ANÆSTHESIA & ANÆSTHETICS

LITCH.

1507 WALNUT STREET,
PHILADELPHIA.

October 19th 1895

Mr William James Morton
Dear Sir:

By this mail I forward a reprint of my article on "Anaesthesia and Anaesthetics" written for "The American System of Dentistry". It contains a page or two (pp. 212-13) on the application of electricity for anaesthetic purposes in dentistry, and represents about the status of that phase of the subject when the article was written, in 1886. There is now a growing interest in the possibilities of electricity in dental practice and need for a better knowledge of the general principles upon which its employment as a therapeutic agency is based. I trust that you may be induced to prepare an exposition of those principles for the use of the profession your father adorned.

Sincerely Yours
Wilbur F. Litch

PART I.

ANÆSTHESIA AND ANÆSTHETICS.

ANÆSTHESIA AND ANÆSTHETICS.

By WILBUR F. LITCH, M. D., D. D. S.

History.

The use of the term "anæsthesia" as designating the state of unconsciousness produced by the inhalation of volatile narcotic agents was first suggested by Oliver Wendell Holmes,[1] and, notwithstanding its inapplicability from the strictly etymological standpoint, and although terms more precise in their significance have since then been proposed—such as *nodynia*, favored by Sir James Y. Simpson, who has expressed regret that he did not adopt it, or *analgesia*, preferred by Prof. Roberts Bartholow, each word signifying loss of consciousness of, or loss of sensibility to, pain—the term "anæsthesia" has become firmly fixed in usage, and is to-day "repeated by the tongues of every civilized nation of mankind."

Although anæsthesia as now practised in surgical operations is of very recent origin, methods for producing insensibility to pain were not unknown to earlier civilizations. Whatever knowledge of pain-obtunding processes the ancient Greeks and Romans possessed was probably chiefly derived from Egyptian sources. Homer in the following passage ascribes such an origin to the draught which Helen gave to Menelaus and his guests:

"Then Helen, daughter of Zeus, turned to new thoughts. Presently she cast a drug into the wine whereof they drank—a drug to lull all pain and anger and bring forgetfulness of every sorrow. Whoso should drink a draught thereof when it is mingled in a bowl, on that day he would let no tear fall down his cheeks, not though his mother and his father died, not though men slew his brother or dear son with the sword before his face and his own eyes beheld it. Medicine of such virtue and so helpful had the daughter of Zeus, which Polydamnia, the wife of Thon, had given her, a woman of Egypt, where

[1] In a letter to Dr. Morton, dated Boston, Nov. 21, 1846, in which he says, "Everybody wants to have a hand in a great invention. All I will do is to give you a hint or two as to names—or the name—to be applied to the state produced and the agent.

"The state should, I think, be called '*anæsthesia.*' This signifies insensibility—more particularly (as used by Linnæus and Cullen) to objects of touch.

"The adjective will be '*anæsthetic.*' Thus we might say 'the state of anæsthesia' or 'the anæsthetic state.' The means employed would be 'the anti-æsthetic agent.' Perhaps the an-æsthetic agent, but this admits of question.

"I would have a name pretty soon, and consult some accomplished scholars, such as Professor Everett or Dr. Bigelow, Sr., before fixing upon the terms which *will be repeated by the tongues of every civilized nation of mankind.*"

earth the grain-giver yields herbs in greatest plenty, many that are healing in the cup, and many baneful."[1]

The intoxicants or narcotic agents chiefly used by the Egyptians were opium, hyoscyamus, and Indian hemp, either singly or in combination. Prosper Alpinus, in his work on Egyptian medicine, clearly describes the intoxicating effects of the latter agent, and gives a formula for an electuary into which it enters in combination with opium, hyoscyamus-seeds, and other substances. The same author[2] states that the Egyptians used burning cotton and flax ("gossypii et lini") for the actual cautery, thereby producing a condition of stupor in which the suffering was much less intense than when the hot iron was used. It is very possible, as suggested by Dr. Sansom,[3] that instead of flax Indian hemp is here meant, and that the comparative insensibility to pain was due to the inhalation of its fumes. Color is lent to this suggestion by the fact, as stated by Herodotus in commenting upon the use of the vapor of hemp-seed in the vapor-baths of the Thracians, that the hemp which grew in Scythia was very like flax, and that "the Thracians make garments of it which closely resemble linen—so much so, indeed, that if a person has never seen hemp he is sure to think they are linen, and if he has, unless he is very experienced in such matters, he will not know of which material they are."[4]

According to the same author, intoxication by the fumes of burning hempseed was a common practice among the Massagetæ, a branch of the Scythian race, which race is believed by Niebuhr to be identical with the Mongols and Tartars. Of this practice Herodotus (book i. chap. 202) gives the following account: "Besides the trees whose fruit they gather for this purpose (food), they have also a tree which bears the strangest produce. When they are met together in companies they throw some of it in the fire around which they are sitting, and presently, by the mere smell of the fumes which it gives out in burning, they grow drunk, as the Greeks do with wine. More of the fruit is then thrown on the fire, and, their drunkenness increasing, they often jump up and begin to dance and sing. Such is the account which I have heard of this people."

Another branch of the Mongolian race, the Chinese, appears to have used hemp as a surgical anæsthetic as early as the second or third century of our era. In a paper on Chinese medicine, read by M. Stanislas Julien before the French Academy in the year 1849,[5] he alludes to an old Chinese medical work entitled *Koukin-i-tong*, in which is contained an account of this anæsthetic method as practised by one Hoa-tho. It is stated that "he gave the patient a preparation of hemp (*ma-yo*), probably by inhalation, and at the end of some instants he became as insensible as if he had been drunk or deprived of life. Then, according to the case, he made openings and incisions, performed amputations, and removed the cause of mischief: he then brought together the tissues

[1] *Odyssey*, lib. iv., translation of Butcher and Lang, London. 1879.
[2] Prosperi Alpini, *Medicina Ægyptorum*, lib. iii. c. xii. p. 213, ed. 1718.
[3] Sansom on *Chloroform*, pp. 17 and 18.
[4] Rawlinson's *Herodotus*, book iv. chap. 74.
[5] *Comptes rendus*, xxviii. p 195, 1849.

with sutures and applied liniments. After a certain number of days the patient found himself re-established, without having experienced the slightest pain during the operation."[1] The same drug is said to be used by the Hindoo suttee to deaden her sufferings when amidst the flames of the funeral pyre; and it is thought to have been an active ingredient in the "wine of the condemned" spoken of by the prophet Amos (Amos ii. 8) some seven hundred years before the Christian era, as well as in the draught given (with merciful design) to the Saviour upon the cross.

Mandragora, or mandrake, the root of Atropa mandragora, a plant indigenous to Southern Europe, appears to have been for many centuries in common use as an anæsthetic agent, although for a long period prior to the discovery of modern anæsthetics it had fallen into complete desuetude. The roots are described by modern observers as being "two or three feet long, conical, sometimes forked, an inch or more thick; in the fresh state fleshy, whitish, and of a heavy narcotic odor; in the dry state wrinkled, externally brown, but internally whitish."[2]

This root is described by Dioscorides, the Greek physician and botanist, whose celebrated treatise on the materia medica was written during the first century of our era, and an account of it is also given by Pliny in his *Natural History*. The forked character and general shape of the root give it some resemblance to the human form: this fact as well as its peculiar narcotic powers gave rise to many superstitious ideas and observances concerning it, there being a general belief that the plant shrieked aloud when torn from the earth, and that misfortunes were likely to follow those who gathered it unless certain precautions were observed. The following passage indicates that the superstition survived at least as late as the age of Shakespeare:

> "And shrieks like mandrakes torn out of the earth,
> That living mortals, hearing them, run mad."[3]

Pliny states that "persons when about to gather this plant take every precaution not to have the wind blowing in their face, and, after tracing three circles around it with a sword, turn toward the west and dig it up."

[1] Chinese surgeons still practise anæsthesia after the ancient methods. A recent traveller and most intelligent observer, Miss Isabella L. Bird, visited the Tung-Wang Hospital at Hong-Kong, China, and gives the following account of the anæsthetic processes as there conducted:

"No amputations are performed, but there are a good many other operations, such as the removal of cancers, tumors, etc. The doctors were quite willing to answer questions within a certain limit; but when I asked them about the composition and properties of their drugs, they became reticent at once and said that they were secrets. They do not use chloroform in operations, but they all asserted—and their assertions were corroborated by Mr. Ng Choy (governor of the hospital)—that they possess drugs which throw their patients into a profound sleep, during which the most severe operations can be painlessly performed. They asserted, further, that such patients an hour or two afterward are quite cheerful, and with neither headache nor vomiting! One of them showed me a bottle containing a dark-brown powder which he said produced this result, but he would not divulge the name of one of its constituents, saying that it is a secret taught him by his tutor, and that there are several formulas. It has a pungent and slightly aromatic taste" (*The Golden Chersonese and the Way Thither*, p. 111).

[2] *National Dispensatory*, Stillé and Maisch.

[3] *Romeo and Juliet*, iv. 3.

The same author describes the plant as consisting of "two varieties—the white mandragora, which is generally thought to be the male plant, and the black, which is considered to be the female. It has a leaf narrower than that of the lettuce, a hairy stem, and a double or triple root. . . . . Both kinds bear a fruit about the size of a hazelnut enclosing a seed resembling a pear in appearance. . . . . The juice is extracted both from the fruit and from the stalk, the top being first removed; also from the root, which is punctured for the purpose. . . . . Persons ignorant of its properties are apt to be struck dumb by the odor of this plant when in excess, and too strong a dose of the juice is productive of fatal effects. Administered in doses proportioned to the strength of the patient, this juice has a narcotic effect, a middling dose being one cyathus" (a little more than one ounce and a half).

"It is given, too, for injuries inflicted by serpents, *and before incisions and punctures are made in the body* in order to ensure insensibility to pain. Indeed, for this last purpose, with some persons, the odor of it is quite sufficient to induce sleep."[1]

It is of course evident that in this account Pliny has embodied much that is merely a record of current superstitions. This fault frequently detracts from the value of his observations, and casts doubt even upon what is authentic; especially is this true in the domain of medicine, with which as an art he had no practical acquaintance. Many of the statements in the passage just quoted are, however, sustained by the authority of Dioscorides, whose descriptions in this as in many other instances Pliny closely follows.

Dioscorides[2] describes "two genera—the black, supposed to be feminine, of which the leaves are longer and narrower than those of the lettuce," and "the white, said to be masculine," and states that the berries eaten by shepherds produce great stupidity and sleepiness; that the use of the drug promotes parturition ("*ciet atque partus*"), and that it is believed by some persons to stimulate amatory power ("*amatoriis efficax esse*"). Dioscorides further states that "some persons boil the root in wine down to a third part, and strain the decoction, of which they give a cyathus in cases of great distress or suffering in any part, as well as before cutting or burning, that pain may not be felt."

A wine made from the bark of the root is also described: "Three *minæ* (pounds) are thrown into a *cadus* (about eighteen gallons) of sweet wine, and of this three cyathi are given to those who are to undergo cutting or cauterization, as before stated."

Of another species of mandragora—which, Dioscorides states, is also called morion, and which, from the description he gives of the plant, is believed by many to be identical with the Atropa belladonna—it is narrated that "a drachm of it being drank at a draught, or being eaten in a cake or otherwise taken with food, causes infatuation and takes away the use of reason. The person, in the very attitude in which he ate the drug, falls into a deep sleep, and is not master of his senses for

[1] Pliny's *Natural History*, book xxv. chap. 94.

[2] *Pedani Dioscoridis Anazarbæi Medici Antiquissimi*, "De Mandragora," lib. iv. cap. lxxvi.

three or four hours, according to the amount given. Physicians also use this when cutting or burning is necessary."

Celsus, a Latin writer on medicine who is supposed to have lived in Rome during the first century, states, in treating "of the various forms of madness and their cure," that in cases of obstinate insomnia mandrake apples are put under the pillow of the patient.[1]

Apuleius Platonicus, a writer whose personality is somewhat obscure,[2] but who was the author of an extant Latin work on plants and their properties, says in regard to mandragora[3] that "if any one is to have a member mutilated, burnt, or sawn, let him drink half an ounce with wine, and so deeply shall he sleep that the member may be cut away without any pain or sensation."

Aëtius, the Greek physician, who lived probably about the end of the fifth or commencement of the sixth century, alludes to the soporific properties of the drug. He says[4] that "those who have drunk of the root become sluggish, languid, dejected, and cold, and fall into a heavy lethargic slumber, from which they are aroused with difficulty, and, being awakened, they quickly fall backward again asleep."

Paulus Ægineta, the Greek medical writer, who lived a century later than Aëtius, states[5] that "when mandragora has been drunk stupor immediately comes on, with loss of strength and a strong inclination to sleep, so that the affection differs in nothing from that which is called lethargy."

In the writings of the Middle Ages frequent allusions are made to anæsthetic preparations. Thus, Theodoric of Servia, who died in 1298, describes a "soporific confection" made after the formula of Dominus Hugo, as follows:[6] "Take of opium and of the juice of unripe mulberry, of hyoscyamus, of the juice of conium, of the juice of the leaves of mandragora, of the juice of wood-ivy, of the juice of the forest-mulberry, of the seeds of lettuce, of the seeds of burdock which has apples hard and round, and of the water hemlock, each an ounce. Mix all of these in a brazen vessel, and then place in it a new sponge. Let it all boil as long as the sun in the dog-days, until it is all consumed and boiled away in it [the sponge]. As often, moreover, as there is need place the same sponge in warm water for one hour, and then let it be applied to the nostrils until sleep seizes him who is to be incised, and in this state let the surgery be done. This being finished, in order that the

[1] Aur. Corn. Celsi, *De Medicina*, libri octo, Amstelædami, 1713, lib. iii. chap. xviii.

[2] Apuleius Platonicus—or, as he is sometimes called, Lucius Apuleius Barbarus—must not be confounded with the pagan philosopher Apuleius de Madaura, who lived about 150 A. D., and who was the author of the *Metamorphosis of The Golden Ass*, and other works: this mistake has been made by several authors, but the two writers were distinct personages, and what are now recognized as the extant works of Apuleius de Madaura do not contain the *De Herbarum Virtutibus* from which the passage quoted is taken, although it has incorrectly been placed in certain editions of his writings. Some authorities claim (see *Nouvelle Biographie générale*, Paris, 1857) that the name Apuleius attached to that work was a pseudonym, and that its real author was one Celsus, a Sicilian physician who lived during the second half of the fourth century, and who was the preceptor of Valens and Scribonius Largus.

[3] Apuleius Platonicus, *De Herbarum Virtutibus*, Basiliensi, 1528, cap. 131, line 22 *et seq.*

[4] Aëtii, *Medici*, Quartæ Sermo I. cap. lxviii.

[5] Lib. v. sect. xliv.

[6] Theodorici, *Ars Chirurgica*, lib. iv. cap. viii., "De somniferis distillationibus."

patient may be aroused place another sponge dipped in vinegar frequently to his nostrils."

Baptista Porta[1] quotes Dioscorides on the sleep-producing power of mandrake, and cites from Junius Frontinus an apocryphal account of a stratagem said to have been practised by Hannibal against certain warlike rebels in Africa—namely, that of mixing mandrake with wine, counterfeiting a flight, and leaving the wine in his camp to be consumed by the enemy, who, being soon overcome by its effects, were then easily put to the sword.

Porta also describes[2] how "a sleeping-apple is made of opium, mandrake, juice of hemlock, the seeds of henbane, and adding a little musk to gain an easier reception to the smeller: these, being made up into a ball as big as a man's hand can hold, and often smelt, do gently close the eyes and bind them with a deep sleep." He also states[3] that "out of many of the afore-named dormitive menstruis there may be extracted a quintessence which must be kept in leaden vessels very closely stopped, that it may not have the least vent, lest it should flie out. When you would use it uncover it, and hold it to a sleeping man's nostrils, whose breath will suck up this subtile essence, which will so besiege the castle of his senses that he will be overwhelmed with a most profound sleep, not to be shook off without much labor. After sleep no heaviness will remain in his head, nor any suspicion of art. These things are manifest to a wise Physitian, but to a wicked one obscure."

In quoting this passage, Dr. Silvester states (*Administration of Anæsthetics in Former Times*) that "there is much reason to believe that alcohol and ether were in the hands of the initiated, and employed in the extraction or solution of the active qualities of plants and herbs;" and in support of this opinion a formula for an *aqua ardens* (from Albertus Magnus, *Mirab. Mundi*, p. 216) is referred to, its chief ingredients being "strong, old, dark-colored wine, quicklime, and common salt distilled into an alembic and kept in a glass vessel." Certainly from the distillation of such a mixture it is very possible that an ether or chloroform might be formed.

Mandrake is also described by Bullein, an early English writer, who states[4] that "this herbe is cold in the third degree, and hath virtue to cause deep sleep: the strength is in the apple and in the rind of the root. The remnant—that is, the leaves and inward parts of the root—is but weak, sayeth Galen. . . . . The juice of this herb, pressed forth and kept in a close earthen vessel according to arte, bringeth sleepe, and casteth men into a trans or a deepe terrible dreame, until he be cut of the stone."

Dr. Madden[5] quotes at second hand from Turner's *Herball*, published in 1551, an account of a wine "of the roots of the mandrake, to be given to persons who had to be cut, scarred, or burned, and they shall feel no pain, but they shall fall into forgetfulness and sleepy drowsiness."

[1] *Natural Magic*, by John Baptista Porta, a Neapolitaine, in twenty books, London, 1658, lib. ix.

[2] *Ibid.*

[3] *Ibid.*

[4] Bullein's *Bulwarke of Defence against all Sickness, Soarness, and Wounds that doe dayly assault Mankinde*, London, 1579, p. 44.

[5] *Dublin Journ. Med. Science*, vol. lix. pp. 32–38.

Not only mandragora, but other narcotics, appear to have been used for anæsthetic purposes. Dr. Rice[1] quotes J. Canape (or Canappe), physician to Francis I., as speaking of the procedure of Theodoric and others, and referring to the dangers of the internal administration of narcotics, as follows: "*Les autres donnent* opium à boire, et font mal, spécialement s'il est jeune, et l'aperçoivent; car cest avec une grande bataille de vertu animale et naturelle. J'ai ouï qu'ils encourent manie, et par consequent, la mort."[2]

There is abundant evidence, too, that as late as the sixteenth century stupefying agents were frequently given to criminals about to be submitted to torture, for the purpose of relieving their sufferings. Sir James Y. Simpson[3] quotes the following:[4] "As to their artifices not to feel the pain of the rack, I saw in the first year of my reception at the bar of Beaujolais, which was in the year 1588, that one of four thieves who were prisoners, the chief, named Grand François, a man of gigantic stature, was put to the rack, fell asleep, and the toes were torn from both his feet without his manifesting any signs of pain. One of his companions observed that he had eaten soap, which stupefied the nerves. The remedy to the artifice is to give wine, which being brought and drunk, he then said he was dead, and without any further torture freely confessed an infinite number of murders and robberies, to atone for which he and his companions were broken in the wheel by sentence of Master Thomassot, provost of the mareschals in Beaujolais."

The frequent allusions to the virtues of mandragora in popular literature, even as late as the time of Shakespeare, seem to indicate a widespread belief in its anæsthetic power. Thus in the *Metamorphosis* of Apuleius,[5] a physician who had been solicited to furnish poison for a criminal purpose is made to say, "I gave him not poison, but the somniferous mandragora, famous for the torpor which it occasions, and which produces a sleep most similar to death;" the result of this substitution being that the victim of the intended crime was rescued from the grave in which he had been placed just as the effects of the poison had begun to be dissipated.

It was doubtless a similar potion which Shakespeare had in mind as causing Juliet's death-like slumber in the tomb of the Capulets, for his dramatic works contain several allusions to the drug and its soporific powers. Cleopatra exclaims,

> "Give me to drink mandragora, ...
> That I might sleep out this great gap of time
> My Antony is away."[6]

And Iago soliloquizes:

> "Not poppy nor mandragora,
> Nor all the drowsy syrups of the world,
> Shall ever medicine thee to that sweet sleep
> Which thou owedst yesterday."[7]

[1] *Trials of a Public Benefactor*, p. 75.
[2] *Les Guidon pour les Barbiers et les Chirurgiens*, Lyons, 1538. [3] *Anæsthesia*, p. 7.
[4] *Le Procès criminal*, by Claude Lebrun de la Rochette, book ii. p. 144.
[5] Apulei Madaurensis Platonici, *Metamorphoseon*, sive Lucus Asini, Francofurti, anno MDCXXI., lib. x. chap. xxxv.
[6] *Ant. and Cleo.*, i. 5. [7] *Othello*, iii. 3.

The tragedy of *Women, beware of Women*, written by Middleton and published about 1657, contained the following allusion :

> " *Hippolito.* Yes, my lord.
> I make no doubt, as I shall take the course
> Which she shall never know till it be acted,
> And when she wakes to honor, then she'll thank me for it.
> I'll imitate the pities of old surgeons
> To this lost limb, who, ere they show their art,
> Cast one asleep, then cut the diseas'd part;
> So out of love to her I pity most
> She shall not feel him going till he's lost."

This figure was made use of nearly a century earlier by Du Bartas in his poetical account of the creation of Eve from a rib taken from the side of Adam[1] during sleep :

> " Even as a surgeon, minded off to cut
> Some cureless limb, before in use he put
> His violent Engins on the vicious member,
> Bringeth his Patient in a sense-less slumber,
> And grief-less then (guided by use and art),
> To save the whole, sawes off the infected part:
> So God empal'd our Gransire's lively look,
> Through all his bones a deadly chillness strook,
> Siel'd-up his sparkling eye with Iron bands,
> Led down his feet (almost) to Lethe's Sands.
> In brief, so nummed his Soules and Body's sense
> That (without pain) opening his side, from thence
> He tooke a rib, which rarely he refin'd,
> And thereof made the mother of mankind."

The following references to somniferous drugs occur in the *Decameron* of Boccaccio, written during the fourteenth century : " He (the Abbot) was never without a certain kind of drug, which, being beaten into powder, would work so powerfully upon the brain, and all the other vital senses, as to entrance them with a deadly sleep, and deprive them of all motion, either in the pulse, or any other part else, even as if the body were dead indeed ; in which operation it would so hold and continue, according to the quantity given and drunk, as it pleased the Abbot to order the matter. This powder or drug was sent him by a great Prince of the East."

And in another of the same series of novels the following is related : " It occurred that the surgeon had in hand a patient, one of whose limbs was diseased, and knowing whence the evil proceeded, told the man's friends that if a rotten bone in the leg was not removed it would be necessary to cut off the limb or the patient would die, but by removing the bone it might be cured : however, he would not undertake the operation unless the patient were given up as dead. To this the family agreed. The surgeon, thinking that if the patient were not sent to sleep he would be unable to bear the pain, and would not permit the operation, deferred performing it till the following morning ; and distilled in the morning a water of a certain composition of his own, which, when the patient had drunk of it, would keep him asleep as long as the operation might last."

[1] *The Works of William de Sallust du Bartas*, translated by Joshua Sylvester, London, 1595.

Dr. Silvester quotes[1] the following from a translation of A. G. Meissner's *Skizzen* (or *Sketches*), a German work published in Carlsruhe A. D. 1782: "Augustus, king of Poland and elector of Saxony, suffered from a wound in his foot which threatened to mortify. The court medical men were opposed to the operation of amputation, but during sleep, induced by a certain potion surreptitiously administered, his favorite surgeon, Weiss, a pupil of Petit of Paris, cut off the decaying parts. The regal patient was disturbed by the proceeding, and inquired what was being done, but on receiving a soothing answer he again fell asleep, and did not discover till the following morning, after his usual examination, that the operation of amputation had really been performed."

Pliny has indicated[2] a method for producing local anæsthesia. He says: "There is also a marble known as 'memphites,' from the place (Memphis in Egypt) where it is found, and of a nature somewhat analogous to the precious stones. For medicinal purposes it is triturated and applied in the form of a liniment with vinegar to such parts of the body as require cauterizing or incision, the flesh becoming quite benumbed, and thereby rendered insensible to pain."

The local anæsthesia (if any) thus obtained was probably due to the effect of the carbonic acid gas evolved during the reaction between the acetic acid and the calcium carbonate.

A more apocryphal statement concerning this same stone is made by the celebrated philosopher and theologian, Albertus Magnus, sometimes called "Doctor Universalis," who was born about 1200 A. D. He says:[3] "To prevent any one from feeling pain or torture take of the stone which is called memphites, from the city which is called Memphis, and which, according to Aaron and Hermes, is of such virtue that if it be pulverized and mixed with water, and given to drink to him who is about to be cauterized or who is about to suffer any other kind of pain, he, so much does this drink induce insensibility, will not feel any pain whatever."

This is doubtless purely fabulous, and the efficacy of the formula for a soporific confection given by Theodoric (see p. 23) may be received with almost equal doubt.

In this connection it is perhaps worthy of note that Dr. Rice quotes M. Dauriol, "a French physician residing in the neighborhood of Toulouse," as asserting in the *Journal de Médecine et de Chirurgie de Toulouse* (January, 1847) "that in 1832 he followed the directions given by Theodoric, and operated several times (five) with success." But, so easy is self-deception in medical practice, this unsupported statement can hardly be accepted as conclusive. As has been pointed out by Snow, the active principle of the plants employed in the formula of Theodoric are not sufficiently volatile in their character to be given off at the temperature of the boiling water in which it is directed that the sponge shall be immersed before placing it to the nostrils of the patient, and the only possibility of narcosis resulting from such a procedure was from the accidental intrusion of the liquid contents of the sponge into his mouth or nostrils.

[1] *Medical Gazette*, vol. vi. p. 513.

[2] *Natural History*, book xxxvi. chap. ii.

[3] Alberti Magni, *De Secretis*, etc., MDCXXXVII. lib. ii., "De Virtutibus Lapidum."

A greater degree of probability attaches to certain of the statements concerning mandragora which have been quoted in preceding pages. Indeed, the experiments made with this drug by Dr. Benjamin W. Richardson[1] fully establish the fact that, internally administered, it possesses a high degree of narcotic power. Dr. Richardson found the active principle of the root to be insoluble in absolute alcohol, but, like atropia, most soluble in water; he therefore made a weak tincture, using only one part of alcohol to five parts of water, which was much after the manner of the ancients, whose most potent preparations of the drug were either decoctions or infusions in wine. The tincture thus made he "found to possess the most active properties—properties faithfully represented by the ancients in their observations."

He found that whether administered by the mouth or by subcutaneous injection the active principle is absorbed with great rapidity: the effects produced are those of narcotism—dilatation of the pupil, paralysis of motion and sensation, excitement during the stage of recovery if the dose be not fatal, and sleep and paralysis if the dose be too potent; "that given to human subjects in doses not sufficient to produce actual narcotism, the symptoms produced are desire for sleep, a sense of fulness in the vessels of the head, a peculiarly enlarged and confused vision. . . . . These symptoms are not actually removed for two days, and they leave a lingering uneasiness and a coldness still longer," thus showing a remarkable slowness in the elimination of the poison from the system, and in a measure justifying the statements made by ancient writers concerning the long duration of its influence.

In concluding the account of his investigations Dr. Richardson says: "There are as yet many new facts to be learned respecting this old medicine and poison, mandragora. We have still to separate its active principle and to determine the relation of that body to atropine. Two facts are, however, now certain in regard to it: that many of the old and discredited statements on the influence of mandragora are perfectly credible. The physiological fact is, that the active principle of mandrake is a narcotic, possessing, when carried to an undue extent, poisonous properties, and that its action is to paralyze the nervous centres that exert a controlling or resistant influence on the minute vascular circulation."

These more recent researches of Dr. Richardson confirm the opinion expressed nearly thirty years earlier (1847) by Dr. Francis Adams in his commentary on, and translation of, Paulus Ægineta (vol. iii. p. 241), that "although it [mandragora] has now disappeared from our dispensatories, we see no good reason why its well-regulated use might not be revived." But, as has already been intimated, surgery during the period immediately preceding the discovery of modern anæsthesia had almost ceased to look or to hope for the merciful ministrations of a pain-obtunding agent; only now and then was a hint such as this given that it was still thought of as a possibility.

An earlier and more significant observation was made in the last years of the last century by Sir Humphry Davy, who in the year 1798, he being not then twenty years of age, was selected for the position of

[1] *British and Foreign Medico-Chirurgical Review*, Jan., 1873.

superintendent of a pneumatic institution established by Dr. Thomas Beddoes at Clifton in the suburbs of Bristol, England, for the purpose of ascertaining by experiment the medicinal virtues of certain of the newly-discovered gases. Although so young, Davy was in the highest degree qualified for his task. He had since 1795 been regularly apprenticed to a surgeon and apothecary, and had entered with enthusiasm upon his medical studies, especially the branches of natural philosophy and chemistry. The time, too, was peculiarly propitious for original investigation in the domain of pneumatic chemistry. Black had proved the existence of a gaseous substance other than atmospheric air; Priestley had discovered oxygen gas and nitrous oxide; and Lavoisier had shown that oxygen supported flame and respiration; hydrogen had been examined in the pure state by Cavendish, and the foundation of modern chemistry laid by his discovery of the formation of water by the union of the two gases. These and the rapidly-succeeding isolation of other gases, such as nitrogen by Rutherford and chlorine by Scheele, could not fail to excite in the minds of men the highest degree of interest and expectancy. Ignorant of the true possibilities and limitations of the newly-discovered substances, the hope was entertained that they would exercise a vast and direct influence in ameliorating the miseries of mankind through the cure of disease. This thought it was which led to the establishment of Dr. Beddoes's pneumatic institution. The idea, however, proved illusory: no very great amount of success was ever attained, although at one time Davy wrote hopefully about it, saying, "Our patients are becoming daily more numerous, and our institution, in spite of the political odium attached to its founder, is respected even in the trading city of Bristol. I shall soon send you an account of the success we have had in curing some of the most obstinate diseases by new remedies. The nitrous oxide we have found very beneficial in many cases of palsy."[1]

Davy also records in his *Researches concerning Nitrous Oxide,* first published in 1800, instances in which headache was cured by this agent, and gives the following illustration of "the power of the immediate operation of the gas in removing intense physical pain:" "In cutting one of the unlucky teeth called dentes sapientiæ I experienced an extensive inflammation of the gum, accompanied with great pain, which equally destroyed the power of repose and of consistent action. On the day when the inflammation was most troublesome I breathed three large doses of nitrous oxide. The pain always diminished after the first four or five inspirations; the thrilling came on as usual, and uneasiness was for a few minutes swallowed up in pleasure. As the former state of mind, however, returned, the state of the organ returned with it; and I once imagined that the pain was more severe after the experiment than before."[2]

Much more significant is the following suggestion: "As nitrous oxide in its extensive operation appears capable of destroying physical pain, it may probably be used with advantage during surgical operations in

[1] *Memoirs of the Life of Sir Humphry Davy,* p. 81.

[2] *Researches, Chemical and Philosophical, chiefly concerning Nitrous Oxide, or Dephlogisticated Nitrous Air, and its Respiration,* by Sir Humphry Davy, Bart., p. 276.

which no great effusion of blood takes place."[1] This suggestion, so illustrative of the keen insight and marvellous prevision of this great master of inductive chemical philosophy, was unheeded, and Davy's connection with the pneumatic institution being soon after terminated by his acceptance of the professorship of chemistry in the Royal Institution of Great Britain, his genius was diverted into channels of chemical research less associated with medical or surgical practice, and so he failed to pursue a line of investigation he was so pre-eminently qualified to follow, and the continued prosecution of which would doubtless have resulted in the speedy discovery of a practical anæsthetic process.

In 1828, Mr. Hickman, a London surgeon, wrote a letter to Charles X., king of France, in which he asserted "that he had discovered the means of performing the most troublesome and dangerous operations without pain. The method consisted in producing temporary insensibility by the methodical introduction of certain gases in the lungs. Mr. Hickman had made numerous experiments on animals, and was desirous of obtaining the co-operation of the leading physicians and surgeons of Paris in order to make the same experiments upon the human subject."[2] This letter was reported to the French Academy by M. Gérardin, but as it contained no specific statement concerning the nature of the gases employed, little attention was given to it either in France or England, and, Mr. Hickman dying soon after, his secret died with him. By some it has been conjectured that his anæsthetic agent was diluted carbon dioxide.

As illustrative of the difficulties of surgical practice before the discovery of anæsthesia, and of the extreme measures which were sometimes resorted to, the following case reported[3] by "James Wardrop, Esq., Surgeon Extraordinary to the Prince Regent," is of great interest. Mr. Wardrop alludes to the difficulties attending operations upon young children where "mechanical neatness or dexterity is necessary," he recommending in the latter class of cases "enclosing all the body except the part to be operated upon either in a bag or wooden box." He also states that it was not uncommon to find adults who could not summon courage enough to submit to the knife, and says that "examples are by no means rare where persons have suffered severe distress, or even died, from disease which they were convinced might have been relieved by a surgical operation."

He then describes the case of a young woman "of a robust form" who "had a tumor on the orbitar (*sic*) plate of the left frontal bone," and says: "Though she had come from a distance determined to get the disease removed by an operation if it was considered advisable, yet when the scalpel touched the integuments she made a violent resistance. A second attempt was made, having previously secured her on a table with numerous assistants, but such was the force and exertion she made to extricate herself whenever the operation was about to be begun that

[1] *Researches, Chemical and Philosophical, etc.*, p. 329.

[2] *Archives générales*, vol. xviii., First Series, p. 453, or *Medical Times* of London, vol. xvi. p. 444.

[3] *Medico-Chirurgical Transactions*, 1819, pp. 273–277.

every hope of success was abandoned. As the only resource it then occurred to me that if she would allow herself to be bled to a state of deliquium the tumor might be extirpated while she remained insensible.

"After a few days she submitted to this measure, and a large vein was freely opened while she sat in the erect posture in a very warm room, in which there were seven people, with the doors and windows kept shut to hasten her fainting. No less than fifty ounces of blood were drawn before she fainted, and then a complete state of syncope came on, which lasted a sufficient time to allow the tumor to be removed. . . . . When the fainting went off she would not believe that the operation had been performed until she examined her face in a glass. . . . . She rapidly recovered her strength without in any way appearing to have suffered from the loss of blood."

Mr. Wardrop did not at all recommend this method of practice for general adoption, but states that he was emboldened to adopt it "from having almost universally observed that those patients recovered from operations best who lost the greatest amount of blood—a fact strikingly illustrated in the battle of Waterloo, when it was found that the wounded who were left in the field, and not taken into hospitals till the fourth or fifth day after the battle, recovered much sooner than those who were immediately attended to." This difference, according to Mr. Wardrop, "could only be accounted for by the bleeding from the wounds being so extensive as to produce syncope, thus preventing inflammation and fever." Modern pathology, it is hardly necessary to remark, would certainly attach to it quite a different significance.

That one of the most marked physiological effects of alcohol narcosis is a more or less complete anæsthesia has long been a generally recognized fact, and the annals of surgery furnish many cases in which painless operations have been performed upon patients while under the influence of this agent.

Richerand[1] remarks that it is well known how easy it is to operate (for luxations) upon drunken people, and recommends the use of wine, "pousseé jusqu'a l'ivresse," to produce muscular relaxation.

Lallemand and Perrin[2] quote Percy as relating that certain bone-setters administered warm wine to their patients for the purpose of obtaining in the sleep of drunkenness insensibility and muscular paralysis, and that he had seen reduced by this means a luxation of the shoulder in which several attempts without the wine had failed.

The case of Deneux is also quoted, in which he states that a woman "upon the point of being confined was carried to the Hôtel Dieu d'Amiens in a comatose state caused by the abuse of alcoholic drinks, she having been in this state at the commencement of her labor. She was delivered naturally during this condition of drunkenness, and her sleep of ebriety continued for a considerable time after her deliverance. Upon awakening she was greatly astonished to see her accouchement ter-

[1] *Nosographie chirurgicale ou Nouveaux Élémens de Pathologie,* tome troisième, pp. 192–194.

[2] *Du Rôle de l'Alcool et des Anesthésiques dans l'Organism,* par Ludger Lallemand et Maurice Perrin, Paris, 1860, p. 13.

minated, and felicitated herself upon having found so happy a method, and avowed her determination to avail herself of it upon the first occasion."

Lallemand and Perrin also refer to the case of Blandin,[1] in which he amputated the thigh of a man found dead drunk in the public highway, the man not experiencing the slightest sensation during the operation.

Several cases equally remarkable are referred to by a writer on "Painless Operations in Surgery" in the *North British Review*,[2] one case being that of an Irishman "part of whose face was eaten by a pig while he was lying dead drunk on the ground," and another, that mentioned by Professor Quain, "where a man in a state of intoxication fell from a coach, and had a shattered leg amputated; on coming to himself he affirmed that he knew nothing either of the accident or the operation." The above writer also quotes Mr. Lawrence as saying that "many years ago a middle-aged woman was brought into St. Bartholomew's drunk with a compound fracture and other serious injury of the leg requiring amputation. Having reflected on the circumstances, I could see no reason why the state of intoxication should prevent the performance of an operation absolutely necessary, and I accordingly removed the limb at once above the knee in the ward. The gentlemen present and myself were perfectly satisfied that the patient was unconscious of the proceeding, though, being subsequently jeered on the subject by some of her fellow-patients, she contended that she knew what was done at the time, but did not feel pain."

The claims of mesmerism, or so-called "animal magnetism," hardly demand extended consideration here, although at one time the subject excited widespread interest in all civilized countries, and many remarkable cases are on record in which grave surgical operations were, it is claimed, painlessly performed upon individuals who had been thrown into the "magnetic sleep." Whether these cases were authentic or whether made up of delusion on the one hand and deception on the other, it is not necessary here to discuss. The burden of evidence would seem to indicate that in certain weak and susceptible temperaments there may be, under the impulsion of a stronger will, a state of hypnotism produced in which consciousness and sensation are abolished—a condition closely allied to those peculiar psychological phenomena so frequently manifested in hysteria or in certain states of religious frenzy.

Dr. Rice[3] states that in the year 1849, during a residence in Calcutta, he paid a visit to the public hospitals of the city, where some experiments with animal magnetism were then being made, and that "the trials of the power made there were even carried so far as to have the patients thrown into the insensible state by their merely drinking water which had been magnetized, and which was given them to drink before the operation without their being aware of its character. Some certainly very remarkable results were witnessed. Patients were operated upon without their evidencing pain who, it was averred, were acted upon by no agent but mesmerism. But the effects were by no means certain or uniform: some were not affected at all or were affected

[1] Reported in the *Bullétin de l'Académie de Médecine*, Paris, 1847, t. xii. p. 517.

[2] Vol. vii. p. 103, May, 1847.

[3] *Trials of a Public Benefactor*, p. 79.

in a different manner from what was intended. If, however, there is 'something in it,' the reason is plain why its use could never be introduced into surgical practice. It requires a long time and many continued attempts before the patient can be thrown into a perfect state of general or local insensibility. But few persons are in any degree sensible to the influence, while the real subject who can be thrown into the state of trance is as rare as a white blackbird."

Various attempts to not entirely abolish, but to obtund, sensation have from time to time been made. The method suggested by Mr. J. Moore of London was the compression of the principal nerves of a limb above the point to be operated upon, this compression to be effected by a suitably-shaped instrument with pads and a screw. This method was tested in St. George's Hospital, London, by Sir John Hunter, the case being one of amputation in the lower third of the thigh. The suffering was thought to have been considerably mitigated.

Velpeau states[1] that the practice "extolled by Juvet," of "applying a strap tied tight above the place where the parts were to be divided . . . . is not to be despised in some cases." He also alludes to the practice recommended by some writers of not using the bistoury until they have dipped it into hot oil or hot water to bring it to the temperature of the body or above it, and states that he cannot deny that it gives less pain, but concludes that the difference is not sufficiently important to warrant the introduction of so troublesome a procedure into general practice.

The administration of moderate doses of opium previous to surgical operations, with a view to blunting nervous sensibility, was a plan which found great favor with many. Prof. S. D. Gross[2] says: "I was myself in the habit of employing it for many years in almost every case that fell into my hands previously to the discovery of anæsthetics: I generally preferred morphia to laudanum or opium in substance, and always gave it in full doses, either alone or, when the patient was strong and plethoric, combined with a moderate quantity of tartrate of antimony and potassium, with a view of inducing a greater degree of relaxation and insensibility. I became very fond of the practice, and never, so far as I could determine, experienced any bad effects from it: on the contrary, I know that it was commonly productive of great benefit, not only blunting sensibility, but preventing shock and, consequently, severe reaction." Others, however, claimed that the practice was objectionable, inasmuch as the use of opium impeded a healthy reaction from shock.

The literature of anæsthesia thus far recorded clearly demonstrates the fact that the surgeons of the ancient, mediæval, and modern world were not oblivious to the desirableness of abolishing—or at least obtunding—the pain incident to all surgical operations. Why, the need being so great, a practicable anæsthetic process should not have been discovered and universally adopted at a much earlier period than it was might well be made a subject for curious, if not profitable, speculation.

It is, of course, true that to a greater or less degree all scientific progress is correlated, and that no great thought can be born out of due

[1] *New Elements of Operative Surgery*, vol. i. pp. 22–24.
[2] *A System of Surgery*, vol. i. p. 547.

time. Still, with the discovery of modern anæsthesia, as with the greater number of discoveries in practical medicine or surgery, the existence or nature of these correlations is not so evident. It can hardly be said that the undeveloped state of chemical and physiological knowledge prevented an earlier discovery, because, as a rule, discoveries relating to the powers and properties of drugs are empirical in their character, and, in the past at least, have generally been entirely disconnected from any scientific apprehension of their ultimate chemical and physiological effects. In this regard physiology may be said to owe more to modern anæsthesia than it to physiology.

While it is true that anæsthesia by the inhalation of sulphuric ether could not have been possible before the time of Valerius Cordus—if he be accepted as among the earliest to possess a knowledge of its genesis and properties—or that anæsthesia by nitrous oxide gas could not have been practised before its discovery by Priestley, still, putting aside the whole group of vegetable narcotics, man has from almost the earliest period in his history possessed an agent not so convenient as the more volatile substances now employed, but far safer than many of them, and one with the effects of which in abolishing consciousness and sensation but few races or peoples are not practically familiar. So great are the advantages, direct as well as indirect, arising from anæsthesia in surgery that it cannot be doubted that were other agents lacking alcohol would now be generally resorted to, as, indeed, as a matter of preference, it of late years has been by one American practitioner. And yet hardly more than a decade before the discovery of modern anæsthesia, advanced as chemistry and physiology then were, all search for an anæsthetic agent had, with here and there an exception, been practically abandoned by the medical profession, and the distinguished French surgeon Velpeau, after alluding to the history of the subject, used the following emphatic language: "To avoid pain under incisions is a chimera which is no longer pursued by any one. A cutting instrument and pain in operative surgery are two words which never present themselves separately to the mind of the patient, and of which he must of necessity admit the inevitable association."[1]

In view of this utterance it is of interest to read that at a meeting of the French Académie des Sciences, held Monday, January 18, 1847, the newly-discovered anæsthetic powers of sulphuric ether were under discussion, and that M. Velpeau gave an account of his successes, partial and complete, of his difficulties, etc., and in a foot-note to the published proceedings states: "This very morning (Friday, 22d) I have removed an enormous cancer from the thigh of a man who had not the slightest perception of the operation."[2] So radical a change of opinion was due to the great discovery whose history will now be reviewed.

Discovery of Modern Anæsthesia.

On the evening of the 10th day of December, 1844, an audience had gathered in Union Hall, in the city of Hartford, to witness demonstra-

[1] *Nouveaux Élémens de Médecine opératoire*, p. 10, Bruxelles, 1832.
[2] *Compte rendus*, séance du Lundi, 18 Janvier, 1847, p. 74.

tions in chemistry made by one G. Q. Colton, an itinerant lecturer on that science. Among other experiments an exhibition was made of the intoxicating properties of nitrous oxide gas, inhaled, after the manner of that day, from a bag of oiled silk or other air-tight material. Such exhibitions were then common, and as only stimulating doses were administered audiences were frequently amused by the grotesque and often violent antics of the subjects of the experiment. After the lecture in question several gentlemen of the audience, being interested in the subject, requested that a private exhibition be given them on the following morning, December 11, 1844.

Among those present as spectators the next day was Horace Wells, a practising dentist of Hartford, and also Samuel A. Cooley, a druggist and a citizen of the same town. Mr. Cooley inhaled a portion of the gas with a view to ascertaining its effects upon his own person, and while under its influence ran against and overthrew some of the benches in the hall, thereby producing, unconsciously to himself, several severe abrasions upon his knees. After recovering from the effects of the nitrous oxide his attention was called by the spectators to the apparent violence inflicted upon himself, and upon exposing his knees to those present it was found that the skin was quite badly bruised and broken.

Dr. Wells was an interested observer of this fact, and, according to the testimony of Mr. Cooley, remarked "that he believed that a person could have a tooth extracted while under its influence and not experience any pain." Dr. Wells, having a troublesome wisdom tooth, proposed that a bag be filled with the gas and that the experiment be at once tried in his office. A number of those present, including Colton, Wells, and Cooley, proceeded thither. What occurred there is perhaps best given in the language of Dr. J. M. Riggs, dentist, whose office was in a room adjoining that of Dr. Wells:

"Dr. Wells, a few minutes after I went in and after conversation, took a seat in the operating-chair. I examined the tooth to be extracted with a glass, as I usually do. Wells took the bag of gas from Mr. Colton and sat with it in his lap, and I stood by his side; Wells then breathed the gas until he was much affected by it; his head dropped back. I put my hand to his chin; he opened his mouth, and I extracted the tooth; his mouth still remained open some time. I held up the tooth in the instrument that the others might see it, they standing partially back of the screen and looking on. Dr. Wells soon recovered from the influence of the gas so as to know what he was about—discharged the blood from his mouth, swung his hand and said, 'A new era in tooth-pulling!' He likewise said it did not hurt him at all. We were all much elated, and conversed about it for an hour after."

The practicability of the use of this gas as an anæsthetic in surgical operations, first suggested by Sir Humphry Davy nearly half a century before, was at last verified. There is no evidence, and but little probability, that Wells was acquainted with Davy's observation, and the honor of the first discovery and application of a safe and efficient anæsthetic agent undoubtedly belongs to him.

During the next few weeks nitrous oxide gas was successfully administered by Dr. Wells to several of his patients, and, encouraged by these results, he in the winter of 1844–45 went to Boston—where he had formerly practised dentistry, and which was then, as it is now, the centre of medical education in the New England States—for the purpose of making his discovery known to the medical faculty, and of securing a trial of his invention in surgical operations other than the extraction of teeth. In Boston he called upon Dr. William T. G. Morton, a former pupil, who in 1842 had been associated with him in the practice of dentistry in that city, and asked his assistance in bringing his invention before the medical faculty.

Among those to whom he was introduced by Morton were Dr. C. T. Jackson, chemist, and Dr. J. C. Warren, then professor of anatomy in the Medical School of Harvard University, one of the surgeons of the Massachusetts General Hospital, and perhaps the leading surgeon in the New England States.

As other surgical cases were not immediately available, it was determined to test the anæsthetic in the extraction of a tooth, Dr. Warren consenting that the experiment should be made before his class at the college. Wells, accompanied by Morton, who took with him his instruments, went to the college in the evening, and Wells administered the gas to a patient and extracted a tooth, but, owing either to some defect in the preparation of the gas or the insufficient amount exhibited, the anæsthesia was quite incomplete, the patient made considerable outcry, and the students and other spectators present laughed and hissed, much to the discomfiture of the unhappy inventor, who, filled with chagrin at his failure, returned home the following morning, too much discouraged to make further trial of his process. In a few months he abandoned his profession and engaged in other pursuits.

The visit to Boston was, however, destined not to be fruitless: it cannot be doubted that it had a decisive influence in fixing the attention of Morton upon the subject and of familiarizing his mind with the idea that surgical anæsthesia was possible.

W. T. G. Morton was then in the twenty-sixth year of his age. He had for a number of years been engaged in the practice of dentistry, and, being desirous of obtaining a medical degree, had in March, 1844, entered his name as a medical student in the office of Dr. C. T. Jackson, subsequently, in the autumn of the same year, matriculating in the Harvard Medical School. During the spring and summer of this year his attention was first directed to the subject of anæsthesia through the recommendation to him, by Dr. Jackson, of "chloric ether," a solution of chloroform in alcohol, as a local application for toothache. The successful application of this remedy in several cases caused him to investigate the subject of the physiological effects of ether upon the animal economy. Dr. Jackson informed him of the intoxicating effects he had seen it produce upon medical students, who in that day frequently inhaled it as a matter of experiment, just as they did nitrous oxide gas; and Morton, having full access to his preceptor's library and chemical laboratory, was soon in possession of the leading facts then known upon the subject.

A portion of the summer months was spent in this line of investigation and in experiments made upon birds and other animals, these being without satisfactory results—a failure easily accounted for by the variable and uncertain character of ethereal substances as then prepared. With the following winter came the failure of Wells with nitrous oxide gas, as already related, and Morton, becoming absorbed in professional engagements, gave but little further attention to the subject until the spring of 1846, when he renewed his experiments with ether and succeeded in completely anæsthetizing a dog. Encouraged by this result, he determined to devote himself almost exclusively to the investigation of the subject, and that he might have more leisure for experimentation, and thus the more speedily perfect a practical anæsthetic process, he secured the services of an assistant and placed almost the entire management of his large practice in his hands. Anæsthesia had become the dominant thought of his life.

Morton's first experiments with the human subject were made tentatively upon himself with chloric ether and morphine, and subsequently with sulphuric ether: with neither drug was complete anæsthesia attained. He then, after some persuasion, induced a student in his office, Thomas R. Spear, who had previously inhaled ether at Lexington Academy, where he received his education, to again submit to the experiment. The effect did not extend much beyond the stimulant stage. Another student, William P. Leavitt, then inhaled the ether with equally incomplete results, excitation and not the insensibility sought for being produced. A subsequent analysis of the ether used in these experiments showed that it was an impure article, it containing a large percentage of alcohol, water, and acids, this fact sufficiently accounting for its failure to act.

Morton was not then sufficiently acquainted with the chemistry of the ethers to understand the reason for this variability in the action of different specimens, and he thought that more uniform and satisfactory results might perhaps be obtained by the use of an inhaling apparatus made from a nitrous oxide gas-bag, in which the ether was to be placed, the bag to be provided with a valve for the admission of atmospheric air. He determined to borrow for this purpose a bag from the laboratory of Dr. Jackson, and also, if opportunity offered, to obtain from him such information as he possessed concerning the different qualities and preparations of ether. These inquiries were purposely made in a very guarded manner, he fearing to be forestalled in his invention should Jackson obtain a knowledge of the full scope and purposes of his research.

According to Morton's statement,[1] he led the conversation from Wells's experiment with nitrous oxide to the use of ether, it having, as has been seen, long been known that the effects were analogous. Dr. Jackson remarked that ether might be used—that the patient would be dull and stupefied and unable to help himself, the idea evidently being not so much that pain would be abolished as that in the partially stupefied state resistance would be overcome. Dr. Jackson recommended a highly rectified article of ether, and for an inhaling apparatus gave him a flask to contain the ether, with a glass tube through which the vapor might be drawn.

[1] *Memoir to the Academy of Arts and Sciences at Paris*, 1847.

The results following this conference are perhaps best given in Morton's own words (*Memoir*):

"I procured the ether from Burnett's, and, taking the tube and flask, shut myself up in my room, seated in the operating-chair, and commenced inhaling. I found the ether so strong that it partially suffocated me, but produced a decided effect. I then saturated my handkerchief and inhaled from that. I looked at my watch, and soon lost consciousness. As I recovered I felt a numbness in my limbs, with a sensation like nightmare, and would have given the world for some one to come and arouse me. I thought for a moment I should die in that state, and that the world would only pity or ridicule my folly. At length I felt a slight tingling of the blood in the end of my third finger, and made an effort to touch it with my thumb, but without success. At a second effort I touched it, but there seemed to be no sensation. I gradually raised my arm and pinched my thigh, but I could see that sensation was imperfect. I attempted to rise from my chair, but fell back. Gradually I regained power over my limbs and full consciousness. I immediately looked at my watch and found that I had been insensible between seven and eight minutes.

"Delighted with the success of this experiment, I immediately announced the result to the persons employed in my establishment, and waited impatiently for some one upon whom I could make a fuller trial. Toward evening a man residing in Boston (Eben Frost), whose certificate is in the Appendix, came in suffering great pain and wishing to have a tooth extracted. He was afraid of the operation, and asked if he could be mesmerized. I told him I had something better, and, saturating my handkerchief, gave it to him to inhale from. He became unconscious almost immediately. It was dark, and Dr. Hayden held the lamp while I extracted a firmly-rooted bicuspid tooth. There was not much alteration in the pulse and no relaxation of the muscles. He recovered in a minute, and knew nothing of what had been done to him. He remained for some time talking about the experiment, and I took from him a certificate. This was on the 30th day of September, 1846."

A fortunate combination of circumstances rendered this experiment successful. As there was no muscular relaxation, and as the time was very brief in which the ether was inhaled, it is evident that the anæsthesia had not advanced much beyond the first stage when the tooth was extracted. This would not have sufficed for a prolonged operation, and with a weakened heart the shock resulting from imperfect anæsthesia might have been fatal. The patient, however, was robust and vigorous; the pain of his aching tooth was almost immediately relieved by the first inspirations of ether; he breathed in the vapor eagerly and succumbed readily to its influence; and the tooth was extracted before the tetanic or convulsive stage, usually very violent with muscular men, came on. The limited amount of ether given favored speedy recovery and prevented subsequent malaise.

These highly favorable results all tended to inspire Morton with confidence in the safety of the etherizing process. Any one of the many complications constantly occurring during the administration of anæsthetics, even when given by the most experienced operators, might have so alarmed him as to put a stop to all further experimentation. A fatal result would doubtless have postponed the discovery for many years.

Morton immediately determined to bring his discovery to the attention of the medical profession, and called upon Dr. Warren, who, undeterred by the failure of the nitrous-oxide-gas experiment, promised his co-operation, and soon sent him a written invitation to make a practical test of his invention in the Massachusetts General Hospital.

Upon the appointed day, October 16, 1846, the clinic-room of the hospital was well filled. Among the spectators drawn thither by rumors of the intended experiment were several of the leading physicians and surgeons of Boston. The patient selected by Dr. Warren for the operation was a man apparently about twenty-five years of age, who had a vascular tumor about the size of a horse-chestnut situated on the left side of the neck, the removal of which was somewhat dangerous owing to its relations to important nerves and blood-vessels. A delay of some ten or fifteen minutes occurred in consequence of the non-arrival of Dr. Morton at the hour of his appointment, 10 A. M. Dr. Warren, not caring to wait longer, remarked, "As Dr. Morton has not arrived, I presume he is otherwise engaged;" which observation was greeted with a hearty laugh by the expectant but sceptical audience in waiting. Dr. Warren had just taken up his knife to make the first incision in the tumor when the tardy inventor appeared, and stated as an excuse for his delay that he had awaited the completion of a newly-designed inhaling apparatus. This consisted of a glass globe containing a sponge saturated with ether, the vapor of which was drawn into the lungs through a glass tube, a valvular arrangement preventing the products of expiration from entering the globe and thereby contaminating the anæsthetic. This valvular attachment was the new feature in the inhaler, and had been suggested to Morton only the night before by Dr. A. A. Gould of Boston, and, hardly in a completed state, had been snatched from the hands of the instrument-maker only a few minutes before Morton's appearance in the amphitheatre. Thus with a new and untried inhaling apparatus the success of the experiment was, most unwisely, subjected to an additional hazard.

As a witness to the credibility of his statements in regard to the previous success of his anæsthetic process Morton had induced Mr. Eben Frost, his first patient, to accompany him to the hospital, where he was introduced to the notice of the man about to be operated upon, doubtless with a reassuring effect.

As the administration of the anæsthetic began the scene, as described many years ago by Dr. Morton in the presence of the writer, was not without the elements of dramatic interest. Before him rose, tier on tier, the crowded seats of the amphitheatre where he had often sat as a student, while around him, eager to watch the event, were many of the most learned and skilled physicians and surgeons of the city, some of whom had been his teachers, but who were now about to learn from him a lesson which all their wisdom had not compassed, and yet a lesson so transcendently important that in the interests of humanity they might well have bartered all their science for the one thought teeming in the brain of the obscure man before them.

In some four or five minutes the patient succumbed to the influence of the anæsthetic, and Dr. Warren began to operate, and in five minutes more the tumor was removed. The groans and movements of the patient indicated that sensation had not entirely been abolished, but upon awakening he declared that he had felt no pain, but only a sensation as though the incised parts had been scraped with a blunt instrument. All present were impressed with the great degree of success which had attended the experiment, although Dr. Warren very naturally declared that further trials would be required to settle its value. These followed in rapid succession, the next trial being had the following day, when a woman had a tumor removed from her shoulder by Dr. Hayward, this surgeon operating at the request of Dr. Warren, although it was the latter's tour of duty at the hospital. The operation was entirely successful.

In the following month, November 7, was made what was considered a crucial test, the power of the anæsthetic in capital operations. This consisted in an amputation above the knee by Dr. Hayward, and the excision of the lower jaw by Dr. Warren, the amputation being entirely painless and the suffering incident to the excision being greatly mitigated. The seal of success was thereby placed upon the discovery.

Up to this time the nature of the agent used had not been formally announced; indeed, the odor of the ether had been partially disguised by aromatic oils; still, according to the testimony of Dr. Bigelow, most of the surgeons knew what the active agent in the compound really was. Before the performance of the operations of November 7, however, it was determined by the hospital staff "to decline the use of the preparation until informed what it was;" and this resolve was communicated to Dr. Morton, who in a letter to Dr. Warren immediately expressed his willingness to "give to the surgeons of the hospital any information in addition to that they may now possess," and who subsequently, upon the day of the amputation, publicly announced to the surgeons in the amphitheatre of the hospital that the substance he employed was sulphuric ether, thus removing the objections they had entertained to the use of a secret preparation.

Dr. Morton's action in thus concealing the real nature of his anæsthetic until its success was assured and his position as a discoverer fully recognized can hardly be cavilled at: the simplest dictates of prudence demanded reticence up to that point. But, unfortunately for his fame, he made the effort to control the use of the invention in his own interest by means of letters patent, which were issued to him Nov. 12, 1846, by James Buchanan, then Secretary of State. On December 21, 1846, an English patent was obtained, it being issued, in Morton's interest, to an English citizen, who subsequently surrendered it into Morton's possession through assignment.

Associated with him in the American patent was Dr. Jackson, who had made upon Dr. Morton a demand for five hundred dollars as a compensation for suggestions made and advice given during the progress of his investigations in regard to the nature of ether. Dr. Jackson, by the earnest advice of Mr. Eddy, the patent-agent employed by Morton, who thought it important to have the indorsement of the distinguished chemist's name as a scientific backing to the discovery, was accepted as a joint discoverer, and 10 per cent. of the prospective profits arising from the sale of licenses under the patent was awarded him in lieu of the five hundred dollars which were the amount of his original claim.

Dr. Jackson, although a member of the Boston Medical Society, consented to share in the patent right upon the basis that while the laws of the society provided that no member should deal in secret remedies, the patenting of the invention would destroy its secrecy, and thus his standing in the society would remain unimpaired. This liberal interpretation of the provisions of the code of ethics, however, resulted in but small gain to either of the parties interested: a few office-licenses were sold, but the Government failed to recognize the validity of the letters patent issued by itself: ether came into general use in the army and navy, and, indeed, throughout the country, without compensation to the discoverer.

It is hardly the place to enter into a discussion of the abstract question of patent rights as applied to agents intended for the relief of human suffering: the general disfavor with which such restrictions are viewed is perfectly natural, although, perhaps, not very logical, inasmuch as many inventions in the mechanic arts, in household appliances, etc. are quite as important to human welfare as those which come under the interdicted class. But, apart from this, the degree of censure which should attach to Dr. Morton in the matter under consideration must be determined in the light of all the circumstances under which he was placed. He was not, like Dr. Jackson, a recognized member of the medical profession, and therefore was not in honor bound to an observance of both the letter and spirit of its code of ethics —a code which demands from each the fullest recognition of the rights of all, and from all the unreserved interchange of the fruits of learning, observation, and experience. The dental profession, with which he was associated, had hardly begun to be recognized or organized as such: its first national society and its first college had been but a few years in existence, and the period had hardly elapsed in which, as far as possible, all processes in dental art were the carefully-guarded secrets of men who would impart them only for a consideration, and then under the strictest injunctions of secrecy.

Still, the better element in the dental profession was even then, as will presently be seen, outspoken in its opposition to patents as antagonistic to professional growth and subversive of the general good. Morton knew the sentiment, and should have respected it. Taking all the conditions into consideration, however, the obtaining of a patent by him cannot be accepted as an evidence of moral turpitude: the most that can be said of it is that it was an error in judgment, and this he very speedily recognized and admitted. In a letter to the American *Journal and Library of Dental Science* (vol. viii., No. 1, October, 1847) this avowal is frankly made, and an equally frank explanation is given of the motives by which he was impelled. This passage in the letter perhaps constitutes Morton's best defence, and is here reproduced:

"I feel bound to make an explanation on the subject of the patent which I obtained. My intention had been chiefly to discover something which I could use to advantage in dental operations. The other uses to which it could be put were collateral to my purpose, and I had no desire to interfere with them. But I was advised that if I did not procure a patent my discovery and the instruments by which I administered the ether would be used by other dentists, while I, who had devoted my time, money, and labor to it, and had run all the risks and encountered all the opposition, odium, and ridicule, would receive no greater reward than they. I did not at the time fully realize the manifold uses and extraordinary powers which have since been developed. I was also advised that this would be a dangerous instrument for evil, and that public policy would be subserved by confining its use to responsible parties. I immediately presented the right to all charitable institutions in the United States, together with apparatus to many of them, and made it known that I would give every facility for its use for the smallest compensation in surgical cases, and would sell rights to dentists for a consideration which all would admit to be reasonable. My object was to secure to myself a reasonable return for the discovery and for all that I had undergone and risked in its prosecution. I can sincerely say that I now regret having taken this step, but a man's motives should not be judged by the result: he must be judged according to the circumstances under which he acted. As I have now abandoned all intention of adhering to the patent, I wish also to have the result of my efforts understood. So far from having gained, I have been a pecuniary loser, by this discovery. It took me from my business, which I was obliged to confide to other hands, involved me in outlays bringing no return, and in personal controversies, and now the discovery is freely used by those very persons whose opposition caused me for a time so much loss and inconvenience."

Opposition to Etherization.—The intimation here given that "opposition, odium, and ridicule" was the lot both of the discoverer and his discovery will hardly excite surprise in the minds of those who remember how generally this has been the reward accorded by men to those who have most benefited mankind; and the record of the events now under consideration would not be complete without some reference to the nature and extent of these antagonisms.

Morton found his most active opponents in the ranks of his own profession. In Boston this opposition was organized, a meeting of dentists being called and a committee of twelve appointed, who prepared and published in the leading newspaper of that city a formal protest against etherization, many instances being cited in which failure of the process or injury to the patient, such as continued delirium and pulmonary hemorrhage, had been the result of the use of the agent by Dr. Morton. As a fair specimen of the tone and animus of many of the attacks upon the new agent with which the press of that day was rife, the following extracts are given from a letter written December 15, 1846, by Thomas E. Bond, Jr., M.D., professor of special pathology and therapeutics in the Baltimore College of Dental Surgery, to the editor of the *Boston Medical and Surgical Journal*:[1]

"I protest against the whole business, because I verily believe the great discovery to be utterly useless. If it does not succeed better in Boston than in other places nearer to your humble servant, I would not give a farthing for it. In this part of the world it has utterly failed to do what it ought to do, and unfortunately it has done what it ought not to have done.

[1] Reproduced in the *American Journal and Library of Dental Science*, vol. vii., No. 3, March, 1847.

In one instance it produced distressing sensations about the chest, which warned the inhaler to let it alone, and he has a teasing cough placed to the debtor side of the account. In another the patient did not get insensible, but got drunk, and boxed the surgeon-dentist's jaws as his reward for administering the intoxicating vapor.

"But you will say, 'The cases! the cases! Dr. Bigelow's cases! Dr. Warren's cases! the Massachusetts Hospital cases! are they not satisfactory?' No, Dr. Smith, they are not. They savor prodigiously of 'mesmeric' incantation. Do you remember one Dr. Collins, whom a number of the Boston faculty sent to us some years ago armed with professional certificates, all testifying to his 'charming' powers? Pardon me: we are a little suspicious of our Boston brethren since that time. They are clever men, very clever, but—some of them—a little credulous. . . . . These cases, we are told, are fair examples of the average results produced by the inhalation of ether. It is likely they are, and they convince us that ether has precisely the power it was known to have had at least, as we have evidence at hand to show, twenty-five years ago, when in certain cases it produced a degree of narcotism at the expense of great bronchial irritation, and even, as was then supposed, fatal pulmonary disease. Heretofore surgeons have declined using this agent, because they were aware that lethargy and fatal coma were conditions divided by a line of separation too indistinct to permit of the production of insensibility with impunity, and because pulmonary irritation is a more serious evil than pain.

"The truth is, that what your correspondents are pleased to call, in medical parlance, 'producing insensibility' is, in fact, making people 'dead drunk.' Everybody knows that when a man is in this curious condition he is very insensible to pain. A poor Irishman in this neighborhood while in this state of 'insensibility' had both his legs taken off by a locomotive. He manifested so little 'sensibility' that he was not aroused until a surgeon was amputating the shattered stumps, when he cried out, 'Don't be cutting me; me flesh is aisy to hale.' Can ethereal vapor beat this exploit of whiskey? I trow not. Now, doctor, if we are to induce insensibility by this class of means, I very much prefer whiskey-punch to ether, because it is more certain and more permanent in its effects: it is less dangerous; and lastly, it will be easier to persuade patients to take it. Moreover, I have the same right to patent whiskey-punch for this purpose that Mr. Morton has to patent ether, for I do not know that such an application of the article has been made before."

Very much of the antagonism of which this letter was a manifestation was unquestionably due to Morton's unfortunate patent-right experiment. Dr. Bigelow had offered in extenuation of this mistake the illogical plea that the discovery was primarily one in "mechanical dentistry," and that therefore a patent was permissible. To this the editors of the *American Journal and Library of Dental Science* made the following spirited reply:[1] "The pretensions set up by Dr. Bigelow, that it is proper and right to patent inventions in mechanical dentistry, is too absurd, too offensive to the good sense, honorable feeling, and correct practice of respectable dentists, to be worthy of refutation. There is no conventional understanding among us to permit such patent-mongering. We think, indeed, that we could name quite as many respectable physicians who are disgracing their profession by vending

[1] Dec., 1846, vol. vii., No. 2, p. 195.

nostrums as he can discover dentists of acknowledged standing engaged in such practices."

In another issue of the same journal (October, 1847) occur the following editorial remarks: "A liberal profession like ours, devoted to the amelioration of the condition of humanity, a profession which joins hand in hand with the noble one of medicine and surgery in bestowing happiness and relief on our great brotherhood of the human race, so far as regards the *profession* have no right to secrets and patents; and should any of its members become obstinate in regard to their professed 'rights,' they at once rebel against the spirit of our fraternity, forfeit all claims to our countenance, and should be regarded accordingly."

The same writer states that "Dr. James H. Bickford has addressed to the *London Morning Chronicle* a solemn warning against the use of ether. He denies that the insensibility which it produces is no worse than that of drunkenness or asphyxia. There is a chemical alteration in the vital constituents of the blood; for not only is that deprived of its oxygen and of the power of coagulation—like the black, vitiated blood of malignant and putrid fever—but the corpuscles, whence fibrin is formed, are actually dissolved. Hence the blood takes a long time to regain its life-supporting, flesh-forming character, wounds show wasted edges and refuse to heal, and the patient often sinks into death. The use of ether also tends to produce tubercular consumption of the lungs: in thirty cases of death after the use of ether in the Dublin hospitals the deaths could be traced to recent tubercles believed to be the product of ether." For this and analogous reasons the writer concludes that "the ether excitement has evidently had its day, and is destined soon to be superseded by that healthful reaction of common sense which follows extremes in medicine as well as other sciences."

Even more alarming than the above was the following vaticination, which, according to a writer in the *North British Review*,[1] was but one among the many then rife in the public prints: "It is useful to remind those who surrender themselves unreservedly to experiments of this nature that the vapor of ether, when combining with the air, constitutes an explosive gaseous mixture of the most dangerous kind. . . . . Now, if it be considered that the vapor-laden air inspired by a patient about to be operated on is precisely this explosive mixture, ... an idea may be formed of the fate that awaits the patient if fire should unhappily reach the air which he is inhaling. A sudden explosion will communicate itself to the interior of his chest, tear the bronchi throughout their entire ramifications, and literally reduce to atoms one of the most essential of the organs of life."

"For some time," says the reviewer, "the profession stood abashed at this, and instrument-makers were seized with a fit of contriving so as to avoid all such risk, protecting every accessible point with wire gauze, such as is used in the safety-lamp of Davy, constructing new valves, etc. etc. A simple though bold experiment, however (a lighted paper to the mouth of an etherized patient), put all happily at rest."

Religious objections to the use of anæsthetics were also urged, many, inspired by ignorant fanaticism, claiming that pain being a dispensation

[1] May, 1847, p. 104.

of Providence, it was in contravention of the divine purpose to alleviate or mitigate it through artificial agencies. The opposition to the use of anæsthetics in obstetrical practice was specially formidable, this being chiefly based upon the passage in Genesis (chap. iii. 16): "Unto the woman he said, I will greatly multiply thy sorrow and thy conception: in sorrow thou shalt bring forth children." Prof. Simpson even thought it necessary to devote an entire chapter in his work on anæsthesia to an elaborate argument in proof of the position that the word "sorrow" in this passage does not necessarily involve the idea of physical suffering. He quotes from a letter written by a clergyman to a medical friend, in which anæsthesia is spoken of as "a decoy of Satan, apparently offering itself to bless women; but in the end it will harden society and rob God of the deep, earnest cries which arise in time of trouble for help." Dr. Simpson states that "lecturers on midwifery in London and Dublin publicly adopted the same line of opposition and argument." Even the late Dr. Charles D. Meigs, professor of midwifery and the diseases of women and children in the Jefferson Medical College of Philadelphia, wrote in 1856[1] of the "doubtful nature of any processes that the physician sets up to contravene the operation of those natural and physiological forces that the Divinity has ordained us to enjoy or to suffer." In justice to Dr. Meigs, however, it must be stated that his opposition was based chiefly upon physiological grounds. Upon this basis, too, many surgeons and physicians objected to the anæsthetic procedure in any surgical operation, they affirming pain to be salutary and desirable because promotive of the reparatory process in wounded surfaces.

In Philadelphia the opposition to anæsthesia was very persistent—so much so, indeed, that in the course of a discussion at the meeting of the Philadelphia County Medical Society (April 13, 1852) Dr. H. S. Patterson was constrained to say that "the mass of resistance to the use of anæsthetics has been more obstinate and impregnable here than anywhere else in Christendom, and our hospital—alone among great hospitals—has never permitted their employment."

One of the earliest to recognize the practical value of the new discovery was A. Hill, D. D. S., of Norwalk, Conn., who published his experience in a communication to the *American Journal and Library of Dental Science.*[2] In this he states that he had purchased from Dr. Morton a license for the use of the "Letheon" (the name which had been given to the new agent), and gives a very clear and practical account of his experiences, the following being his conclusions:

"1st. That in the hands of *careful, skilful,* and *judicious* men the Letheon is perfectly safe.

"2d. That where there is a failure it is the result of an imperfect preparation of the vapor or an imperfect inhalation, modified, perhaps, in some cases by peculiar temperament.

"3d. That it is not only safe, but valuable beyond conception in a multitude of cases."

European Recognition.—Outside of Boston, Morton's discovery met with the warmest and most immediate recognition in England. Accord-

[1] *Treatise on Obstetrics.*

[2] Vol. vii., No. 3, March, 1847.

ing to Dr. Bigelow,[1] the first public announcement of surgical anæsthesia was made by him in a paper in the *Boston Medical and Surgical Journal*, Nov. 18, 1846, entitled "Insensibility during Surgical Operation produced by Inhalation, read before the Boston Society for Medical Improvement, Nov. 9, 1846," an abstract having been previously read before the American Academy of Arts and Sciences, Nov. 3, 1846. "A copy of this," says Dr. Bigelow, "was sent by a gentleman to his friend Dr. Booth of London." The important intelligence was immediately communicated by him to Liston, the distinguished surgeon, who, Dec. 21, 1846, in the hospital of the University College, practically and successfully tested the discovery. This result he immediately communicated to his former pupil, Prof. Miller of Edinburgh, in the following enthusiastic epistle:

"Hurrah! rejoice! Mesmerism and its professors have met with a 'heavy blow and great discouragement.' An American dentist has used ether (inhalation of it) to destroy sensation in his operations, and the plan has succeeded in the hands of Warren, Hayward, and others in Boston. Yesterday I amputated a thigh and removed by evulsion *both* sides of the great toe-nail without the patients being aware of what was doing, so far as regards pain. The amputation-man heard, he says, what we said and was conscious, but felt the pain neither of the incisions nor that of tying the vessels. In short, he had no sensation of pain in the operating theatre. I mean to use it to-day in a case of stone. In six months no operation will be performed without this precious preparation. It must be carefully set about. The ether must be washed and purified of its sulphureous acid and alcohol. Shall I desire Squire, a most capital and ingenious chemist, to send you a tool for the purpose? It is only the bottom of Nooth's apparatus, with a sort of funnel above, with bits of sponge, and at the other hole a flexible tube. Rejoice!

"Thine always, R. L."

This letter of course excited the utmost interest in the minds of the profession in Edinburgh, and Prof. Simpson, then professor of midwifery in the University of Edinburgh, soon after visited London, where he had opportunities of seeing practical demonstrations of the success of the new discovery, and, returning home with an inhaling apparatus (which was still considered indispensable), successfully tested it in a case of amputation performed by Dr. Duncan in the Royal Infirmary.

With almost unexampled rapidity news of the discovery spread throughout the civilized globe, and in all civilized countries the anæsthetic process was generally adopted in surgical operations. On Jan. 19, 1847, Dr. Simpson extended its use to the alleviation of the pangs of childbirth in a case of midwifery which came under his care at that date, this being the first case on record.

Chloroform as an Anæsthetic.—In consequence of the unpleasant effects, such as bronchial irritation, etc., sometimes produced by ether inhalation, Dr. Simpson was led to experiment with other volatile agents, and to obtain from his chemical friends all the information he could concern-

[1] "A History of the Discovery of Modern Anæsthesia," *American Journal of Medical Sciences*, Jan., 1876.

ing them. He found in chloroform what he conceived to be an excellent substitute for ether, free from its objectionable features and more prompt in its action. These advantages soon obtained for it so widespread a popularity that for a time it seemed as though etherization would become obsolete, as, indeed, in England it nearly did. So great was the reputation Dr. Simpson obtained through the introduction of chloroform narcosis that the fame of Morton was in the minds of many quite overshadowed. Even so late as 1869 the then Sir James Y. Simpson, upon receiving the honorary burgess-ship of Edinburgh, was greeted by the lord provost, William Chambers, Esq., the well-known author and publisher, as the author of "the greatest of all discoveries in modern times, the application of chloroform to the assuagement of human suffering"—so little were the value and true nature of the service which Morton had rendered to humanity appreciated by even so cultured and intelligent a gentleman as the lord provost in question.

The Ether Controversy.—It is now proposed briefly to review the causes by reason of which Morton's fairly-won fame was thus obscured, and through which opinion is to-day still so divided as to whom should be given the chief credit for so great a discovery. In part, his failure to obtain complete recognition grew out of the somewhat mercenary aspect in which his pretensions to secrecy and his securing of letters patent placed him. This result, however, was of but minor importance. So far as his claims as a discoverer were concerned, the chief mischief arising from the effort to secure control of the anæsthetic agent through a patent was the fact that by the unwise advice, already alluded to, of his patent-agent, Mr. Eddy, he was induced to admit the claims of Dr. Jackson as a joint discoverer.

No sooner was the success of the discovery fully established than the latter came forward as the sole originator of the anæsthetic idea and the instigator of the experimentation conducted by Morton, who, it was claimed, was merely a subsidiary agent in the affair. In order that Morton's claims might be completely forestalled in continental Europe, Jackson, who, as Dr. Bigelow says, "knew the machinery of fame," sent letters to the French Academy of Sciences—one dated November 13, and the other December 1, 1846—in the first of which he announces the discovery, and states that he had *induced* "a dentist" (not even mentioning Morton's name) "of this city to administer the vapor of ether to persons from whom he was to extract teeth," and that he then "*requested* this dentist to go to the General Hospital of Massachusetts and administer the vapor of ether to a patient about to undergo a painful surgical operation." In the second letter he announces the complete success of the experimentation with ether, and that "it has been put into use with full success in the General Hospital of Massachusetts."

These letters were presented to the French Academy by M. Élie de Beaumont, to whose care they had been entrusted by Dr. Jackson, and who had kept them in a sealed packet until the session of January 18, 1847, when they were opened and read. Knowledge of the discovery, however, had reached France at a much earlier period than this, and etherization had been practised by Velpeau and others; but the claim of discovery thus formally presented accomplished, for the time at least, its purpose.

The claims of Morton were subsequently so fully and forcibly presented that they could not be entirely ignored, and the Academy at the session of March 4, 1850, decreed a prize of twenty-five hundred francs to Dr. Jackson, "for his observations and his experiments on the anæsthetic effects produced by the inhalation of ether; and, likewise, another of twenty-five hundred francs to M. Morton, for having introduced that method in surgical practice in conformity with the indications of M. Jackson."[1]

The nature of the claim upon which this award was based will now be examined.

As given by Dr. Jackson himself in a statement addressed to a committee appointed by the House of Representatives of the United States to investigate the subject of the ether discovery (see official Congressional reports), the date of his discovery of anæsthesia by ether vapor was in the winter of 1841–42. During this winter he was engaged in giving lectures on chemistry, and accidentally inhaled a large amount of chlorine gas, which resulted in a severe inflammation of the throat attended by considerable pain, to relieve which he inhaled perfectly pure washed ether, of which he had in his laboratory a large supply. This resulted in loss of feeling and cessation of pain, and finally loss of consciousness, from which he recovered to find the nerves of sensation still partially paralyzed, some time elapsing before his throat became again painful. Reflecting upon this experiment, the idea of etherization during surgical operations flashed into his mind. He states that he, like all educated physicians and physiologists, knew that "the nerves of sensation were distinct from those of motion and of organic life, and that one system might be paralyzed without necessarily and immediately affecting the others;" that he had observed this sequence of influences and results during his inhalation of the ether vapor; and that "this state of insensibility of the nerves of sensation continued for a sufficient length of time to admit of most surgical operations; . . . . that the nerves of motion and of the involuntary functions of respiration and of circulation were in no wise affected, the functions of life going on as usual, while the nerves of sensation were rendered devoid of feeling and the body could suffer no pain. By long experience in the trial of ether vapor in spasmodic asthma, and from numerous carefully-conducted physiological experiments, I had learned that the vapor of ether could be safely inhaled into the lungs to an extent before believed to be highly dangerous."

So that, according to Dr. Jackson's own statement, he had in the winter of 1841–42, by scientific induction based upon partial experimentation, arrived at a full conviction of the possibility of artificial anæsthesia by means of ether vapor during surgical operations, and yet made no effort to put it to practical use until the winter of 1846, when, as the result of an accidental encounter and conversation with Dr. Morton (see p. 36), he mentioned ether to him as a means for stupefying a patient prior to the extraction of a tooth. This reticence is all the

[1] *Comptes rendus.*

more noteworthy because in the winter of 1844–45 he was cognizant of the visit of Dr. Wells to Boston for the purpose of demonstrating his nitrous-oxide-gas discovery, and, indeed, had had an interview with him, and still had given neither to him nor to Morton, his student, any hint as to his knowledge of the fact that ether vapor would accomplish what nitrous oxide gas had failed to effect. Certainly, this withholding of a truth of such importance for so great a length of time is in sufficiently marked contrast with the swift eagerness with which Morton confirmed hypothesis by experiment and made the result known to the whole world. It is true that, according to the sworn evidence of several reputable persons, Dr. Jackson had during the period between 1842 and 1846 suggested etherization to them, but in the greater number of instances it was in connection with chlorine inhalation. Several of the witnesses, however, testify that distinct mention of the possible anæsthetic powers of ether in dental and general surgery was made.

Jackson's failure to make known his discovery is accounted for by his friends by the entire absorption of his time and the preoccupation of his thoughts in geological and chemical research and experimentation; that, having retired from the practice of medicine, he had no facilities for making experiments; and that he "naturally shrank from going to the hospitals, where chemists are regarded with distrust and jealousy by the surgeons, and where, as events have shown, the largest honor of successful experiment would have been claimed by the verifiers." Moreover, it is claimed that it was in keeping with his peculiar mental constitution to be cautious and slow in making his scientific discoveries known to the world, as in the asserted fact of his discovery of chlorine in meteoric iron in 1834, of which he published no account until the year 1838.

From a review of all the evidence it would appear altogether probable that Jackson, as well as Morton, had conceived the idea of artificial anæsthesia by ether. The history of the subject fully establishes the fact that the anæsthetic idea had been, and was, in the minds of many men. Dr. J. C. Warren testifies that *he* had been anxious to find something of the kind proposed by Morton, and had made repeated trials without any satisfactory result; hence, probably, the favorable reception he was prepared to give to Morton's request for an opportunity to test his discovery.

It is in evidence that ether had been suggested to Dr. Wells after his early nitrous-oxide experiments by E. E. Marcy, M. D., and it is even claimed that a surgical operation was performed by the latter in 1844 while the patient was anæsthetized by ether vapor, the use of this agent, however, being abandoned in favor of nitrous oxide gas as being the safer and more reliable of the two.

An even earlier and much better authenticated claim of priority of use is that of Dr. Crawford W. Long of Athens, Ga., who claims to have operated under ether so early as July 3, 1842, and to have repeated the experiment on Sept. 9, 1843, and Jan. 8, 1845, the claim for the operation in 1842 being fully substantiated by the affidavit of the patient and by the usual entry of fee in his daybook.

M. Ducros claims priority, because at the séance of the French

Academy held March 16, 1846, he announced that he had "employed with success sulphuric ether to produce sleep in persons afflicted with hypochondria, and who had for that purpose vainly employed opiates." The method of administration employed by M. Ducros was "frictions upon the tongue, soft palate, tonsils, and fauces," and he stated that, employed in the same manner upon chickens, sleep had been instantaneously produced.[1]

Robert H. Collyer, M. D., of London, writes quite indignantly to the editor of the *Medical Times and Gazette* (Oct. 14, 1871) as follows:

"SIR: Having in my possession the original publication of 1843, wherein I distinctly state that the inhalation of narcotic and stimulating vapors produces an anæsthetic state, prior to which I had performed various surgical operations during this insensible condition, which enabled me to publish the fact in 1843, I cannot now understand how Horace Wells could be named as the originator of modern anæsthesia, when his first essay with nitrous oxide only dates from December, 1844," etc. etc.

Samuel Sexton, M. D., in an article in the *New York Medical Record*[2] calls attention to the use of ether vapor as recorded in a work published in London in 1829 by William Wright, Esq., "Surgeon Aurist to her late Majesty Queen Charlotte," the ether being administered by him in cases where spasmodic cough was liable to be excited by the slightest touch being given to the lining tube of the ear, the method of administration recommended being to put the ether in a receptacle floating in a basin of warm water, the patient breathing in the vapor until all reflex irritability ceased. This plan, he states, was constantly resorted to by himself and patient.

J. Gorringe, Esq., assistant surgeon to the Royal Cornwall Infirmary, in a communication to the *London Lancet*[3] states that while an apprentice to the University College Hospital in the session of 1838–39 he had on several occasions inhaled sulphuric ether from a common bladder until marked intoxicating effects were produced, and that he had a distinct remembrance of two cases of insensibility resulting therefrom, the students falling flat on their backs.

These cases are cited to show that knowledge of the leading physiological effects of ether was not by any means the exclusive property of Dr. Jackson, and that others besides himself had thought of surgical anæsthesia prior to his claimed discovery.

The following quotation from the edition of Pereira's *Elements of Materia Medica*, published in London, 1839—a standard work which Jackson had in his library—shows how much was really known about the drug in question, and how entirely destitute of originality his use of it after inhaling chlorine really was, as well as how thoroughly understood was the analogy between the physiological effect of ether vapor and nitrous oxide gas. Reading this, it is evident that no man acquainted with the facts and giving the slightest attention to the subject could fail, on hearing of experimentation with the one agent for the production of anæsthesia, to think of the other:

[1] *Comptes rendus*, séance du Lundi, 16 Mars, 1846, p. 447.

[2] 1879, vol. xvi. p. 117.

[3] Feb. 13, 1847, vol. i. p. 186.

"The vapor of ether is inhaled in spasmodic asthma, chronic catarrh and dyspnœa, whooping cough, and to relieve the effects caused by the accidental inhalation of chlorine gas. When the vapor of ether, sufficiently diluted with atmospheric air, is inhaled, it causes irritation about the epiglottis, a sensation of fulness in the head, and a succession of effects analogous to those caused by protoxide of nitrogen, and persons peculiarly susceptible to the action of the one are also powerfully affected by the other (*Journ. Science,* vol. iv. p. 158). If the air be too strongly impregnated with ether, stupefaction ensues."

That Morton had a good general knowledge of sulphuric ether, and was not, as claimed by Jackson, wholly ignorant concerning it prior to the visit to his (Jackson's) laboratory, Sept. 30, 1846, is demonstrated by the most positive evidence of reputable chemists, apothecaries, and instrument-makers, who testify that at various times before that date he had made personal inquiries of them about ether; while other witnesses testify to his purchase and possession of samples of that drug. Stronger testimony could not be offered than has been furnished upon these points.

Morton's own statement in regard to his sources of information and the degree of his indebtedness to Jackson very fairly represents the facts in the case. He says:[1]

"I will make a single remark upon the subject of my interview with Dr. Jackson. It is not necessary to go into the question of the origin of all ideas: I am ready to acknowledge my indebtedness to men and to books for all my information upon this subject. I have got here a little and there a little. I learned from Dr. Jackson in 1844 the effect of ether directly applied to a sensitive tooth, and proved by experiment that it would gradually render the nerve insensible. I learned from Dr. Jackson, also in 1844, the effect of ether when inhaled by students at college, which was corroborated by Spear's account and by what I read. I knew of Dr. Wells's attempt to apply nitrous oxide gas for destroying pain under surgical operations. I had great motives to destroy or alleviate pain under my operations, and endeavored to produce such a result by means of inhaling ether, inferring that if it would render a nerve insensible directly applied, it might, when inhaled, destroy or greatly alleviate sensibility to pain generally. Had the ether I tried on the 5th of August been pure I should have made the demonstration then. I further acknowledge that I was subsequently indebted to Dr. Jackson for valuable information as to the kinds and preparations of ether, and for the recommendation of the highly rectified from Burnett's as the most safe and efficient. But my obligation to him hath this extent, no further. All that he communicated to me I could have got from other well-informed chemists or from some books. He did not put me upon the experiments; and when he recommended the highly rectified sulphuric ether, *the effect he anticipated was only that stupefaction which was not unknown, and he did not intimate in any degree a suspicion of that insensibility to pain which was demonstrated and astonished the scientific world.*"

According to the sworn evidence of Caleb Eddy, Esq., of Boston (official reports), Jackson's own words to him confirm this view of the

[1] *Memoir to the French Academy,* July, 1847.

case. Mr. Eddy asked him during a conversation in reference to the new discovery, "Dr. Jackson, did you know at such time" (when recommending ether to Morton) "that after a person had inhaled the ether, and was asleep, his flesh could be cut with a knife without his experiencing any pain?" He replied, "No, nor Morton either: he is a reckless man for using it as he has."

It is very safe to assume that had Morton's "recklessness" resulted in any misadventure Dr. Jackson would not have been nearly so swift to assume a share in the responsibility of the failure as he was to claim all the credit for the success. Dr. Jackson subsequently denounced this "reckless man," Morton, as "an ignoramus and an imbecile, not only not possessed of science, but mentally incapable of acquiring it."[1] It assuredly is but little to the credit of Dr. Jackson's humanity or of his professional discernment that he should have risked human life and perilled the success of his great discovery by placing it in hands so incapable. And yet nothing is more certain than that Morton was permitted to assume the whole responsibility in his grave undertaking. Indeed, so thoroughly aloof did Dr. Jackson hold himself that it was not until the 21st of November, more than a month after the first operation with ether, that he was present during its administration to a patient, and then only as a spectator.

Dr. Jackson's claim to the gratitude of humanity would seem, according to his own showing, to rest upon this: that in the year 1842 he discovered the anæsthetic power of ether, satisfied himself that by its agency the sensory nervous system might be completely narcotized while respiration and circulation remained comparatively unaffected, and that for this reason it might be safely used in surgical operations; that he allowed this great discovery to remain unknown to the world until 1846, and then imperilled the success of his discovery and the interests of suffering humanity by entrusting the administration of so powerful a narcotic as sulphuric ether to the hands of one whom he claims to have known as an ignoramus and an imbecile.

Justice to Dr. Jackson himself would seem to demand that a claim necessarily involving such an implication as this should not be credited. The fact would appear to be that either his ambition or his peculiar mental constitution led him to unduly exaggerate the share he had had in Morton's discovery. Jackson was unquestionably a man of good scientific attainments, and was constantly engaged in general scientific research, and in a vague sort of way had doubtless conceived the idea that ether might be used as a pain-obtunder in surgery—the same idea which Morton and, as has been seen, others hit upon. That the suggestions which he made to Morton should have led him to claim the sole merit of the whole discovery was but in keeping with a previous attempt of the same nature—the claiming in 1837 of the invention of the magnetic telegraph, this assumption being based upon alleged conversations held with Prof. Morse in the year 1832 when they were fellow-passengers during a transatlantic voyage; during which voyage the idea of the electric telegraph was conceived and elaborated in all its essential details by Morse, and by him alone, as was fully and irrefut-

[1] See Majority Report Select Committee of 32d Congress.

ably substantiated before the courts, the judges refusing to concede to Jackson any share, direct or indirect, in the invention.

The claims of the various contestants in the ether controversy also have been fully adjudicated, and before tribunals whose integrity it is impossible to question, and which had the best opportunity of judging of the character of the witnesses and the credibility of their testimony. The case can never again be retried, and their verdict must be accepted as final.

Dr. Morton submitted to the Thirty-second Congress a memorial asking from that body remuneration for his discovery. This memorial was referred to a select committee of the House of Representatives. The majority report of this committee thoroughly reviews all the evidence, and announces the following conclusions:

"1st. That Dr. Horace Wells did not make any discovery of the anæsthetic properties of the vapor of sulphuric ether which he himself considered reliable and which he thought proper to give to the world—that his experiments were confined to nitrous oxide, but did not show it to be an efficient and reliable anæsthetic agent, proper to be used in surgical operations and in obstetrical cases.

"For the rest, your committee have come to the same conclusions that were arrived at by the trustees of the Massachusetts General Hospital at their meeting in January, 1848, and reconsidered" (at the request of Dr. Jackson) "and confirmed in 1849, and adopted by the former committee of the House—viz.:

"2d. That Dr. Jackson does not appear at any time to have made any discovery in regard to ether which was not in print in Great Britain some years before.

"3d. That Dr. Morton in 1846 discovered the facts, before unknown, that ether would prevent the pain of surgical operations, and that it might be given in sufficient quantity to effect this purpose without danger to life. He first established these facts by numerous operations on teeth, and afterward induced the surgeons of the hospital to demonstrate its general applicability and importance in capital operations.

"4th. That Dr. Jackson appears to have had the belief that a power in ether to prevent pain in dental operations would be discovered. He advised various persons to attempt the discovery, but neither they nor he took any measures to that end, and the world remained in entire ignorance of both the power and safety of ether until Dr. Morton made his experiments.

"5th. That the whole agency of Dr. Jackson in the matter appears to consist only in his having made certain suggestions which aided Dr. Morton to make the discovery—a discovery which had for some time been the object of his labors and researches."

The conclusions embodied in this report of the committee of the House of Representatives are fully sustained by the following "Memorial," which may be accepted as the verdict of a "jury of the vicinage." The memorial is signed by all the surgeons and physicians of the Massachusetts General Hospital, and by several hundred of the leading members of the Massachusetts Medical Society, and reads as follows:

"To the Honorable the Senate and House of Representatives of the United States, in Congress assembled:

"The undersigned hereby testify to your honorable bodies that in their opinion Dr. William T. G. Morton first proved to the world that ether would produce insensibility to the pain of surgical operations, and that it could be used with safety. In their opinion his fellow-men owe a debt to him for this knowledge. Wherefore they respectfully ask a recognition by Congress of his services to his country and mankind."

Many of the men who signed this memorial had personal knowledge of the facts; the men who signed the majority report of the select committee of the House of Representatives were accustomed to weigh evidence. From this joint verdict of Morton's contemporaries there can now be no appeal. It is a verdict fully sustained by the authority of Daniel Webster, then Secretary of State. In a letter to Dr. Morton, dated Washington, December 20, 1851, he says:

"In reply to your letter of the 17th inst. I would say that, having been called on, on a previous occasion, to examine the question of the discovery of the application of ether in surgical operations, I then formed the opinion, which I have since seen no reason to change, that the merit of the great discovery belonged to you, and I had supposed that the reports of the trustees of the hospital and of the committee of the House of Representatives of the United States were conclusive on this point.

"The gentlemen connected with the hospital are well known to me as of the highest character, and they possessed at the time of the investigation every facility for ascertaining all the facts in the case.

"The committee of the House were, I believe, unanimous in awarding to you the merit of having made the first practical application of ether, and a majority by their report awarded to you the entire credit of the discovery."

Although Dr. Morton's memorial to Congress asking for remuneration was thus sustained by the committee to which it had been referred, no grant of money was ever made to him, the failure to secure an appropriation for that purpose being chiefly due to the antagonism not only of the friends of Jackson, but of Wells, the latter being very active in asserting his claim to the chief, if not the entire, merit of the discovery. Similar influences caused the abandonment of a subscription for ten thousand pounds which had been started in England on behalf of Morton, and which had at first every prospect of a successful issue.

The trustees of the Massachusetts General Hospital voted him the sum of one thousand dollars, which was presented to him in a silver casket, upon which was engraved this sentence: "He has become poor in a cause which has made the world his debtor." This and the prize from the French Academy, already mentioned, constitute almost the entire sum of the pecuniary recognition which his great service to humanity received.

Jenner, to whom the world owes its present comparative immunity from one of the greatest scourges of the human race, smallpox, received from the British House of Commons thirty thousand pounds as an acknowledgment of the gratitude of the nation for the invention of vaccination. It would be difficult to determine whether Jenner's invention or the discovery of anæsthesia has been the more wide-reaching in its beneficence: both are priceless gifts to mankind, and it is but little to the credit of the American republic that it should have permitted Morton to suffer in mind, body, and estate, and to go down to his grave an impoverished man—"the only person," to use his own language, "in the whole world to whom the discovery was a pecuniary loss."

Jenner's discovery was based upon the observation of a young countrywoman, who, while he was a student at Sudbury, made to him the remark, in connection with the subject of smallpox, "I cannot take the disease, for I have had cowpox," this being a popularly received idea in that district; but the fact that this remark first fixed Jenner's attention upon the subject did not prevent the House of Commons from recognizing the truth that to his persistent and indomitable energy, manifested in the face of storms of obloquy and persecution, humanity owes the demonstration of the scientific truth of what had before been merely surmise.

The same truth should have been recognized—indeed, was recognized—in the case of Morton. Whatever else may be questioned, the fact is undisputed and indisputable that he was the first to demonstrate to the world the practicability of anæsthesia as a system reasonably certain, safe, and uniform in its operations. For this, if for this alone, he should have been rewarded, and with no niggard hand.

Morton in making this demonstration assumed no small risk and responsibility; indeed, his courage has been termed audacity. As Dr. Bigelow says: "Had Morton been a timid or discreet man, anæsthesia might have been delayed beyond the present generation. Morton compelled inhalation in spite of indications to arrest it, incurred the responsibility of doing so, and is entitled to the credit. . . . . A patient was, in fact, in great danger from over-inebriation at the first private operation. He was inhaling, in the continuous way that was at first supposed to be essential to protracted insensibility, through a glass globe of ether, and long after insensibility was manifested. The operation was far from completed when a bystander happened to feel the pulse. There was no special reason for doubt, inasmuch as the patient was, in general appearance, like all former thoroughly-etherized patients. The pulse proved to be barely perceptible, and the patient to be etherized almost beyond recovery. The bystander, after repeated observation of other cases, published the fact, then first observed, that in ether anæsthesia the pulse stood as a beacon between safety and danger, between harmless inebriation and fatal narcotism. This was the discovery that ether was not dangerous, because this showed that its danger gives warning and is under control. The operator was Dr. Dix, the bystander myself, and the discoverer Morton. To his impetuous, unremitting, reckless experimentation to establish anæsthesia, surgeon, bystander, patient, ether, and apparatus were all for the time and in that relation subordinated. Morton had asked me to be present because I was more familiar with the new process than anybody except himself, and for the purpose of aiding him in emergency with professional advice. But the anæsthesia was his: I assumed no responsibility. Had the patient died in a stupor, as he might well have done, Morton was liable; and as the patient did not die, his was the credit. This was real danger. But there was other danger, more startling, though only apparent, such as prostration, 'trance' or 'mania,' lasting for hours, and for which Morton was in one instance threatened with prosecution."[1]

Morton not only assumed these grave responsibilities in the interest of his discovery, but he sacrificed in its behalf all his time and all his means. From the first he was overwhelmed with correspondence upon the subject, and his personal services were in constant demand, and during the whole "ether controversy" he fought for his rights with a magnificent courage and unwearied persistency which must have extorted the admiration of his most determined opponents. He believed in his cause, and was from the first bold, determined, and aggressive in its defence. Through the daily press and through scientific journals, by correspondence with the learned societies both of Europe and America, he made his cause known. Before the various committees appointed by Congress to examine his claims he appeared, and the extent of the labors which these official investigations alone devolved upon him can be appreciated only by those who have examined the voluminous testimony produced, and know that his was the guiding mind which massed it for presentation.

The literature of this controversy fully disproves Dr. Jackson's assumption that Morton was an ignoramus and an imbecile, and makes clearly manifest the fact that he was a man of extraordinary force of character, and that the moral qualities he displayed in defence of his rights as a discoverer were precisely those needed to make his discovery possible.

Beneficence of the Discovery.—Concerning the boundless beneficence of the agency he invoked to steep the pangs of pain in sweet obliviousness all men agree. "It is probable," says Lecky,[2] "that the American inventor of the first anæsthetic has done more for the real happiness of mankind than all the moral philosophers from Socrates to Mill."

The venerable Dr. Warren, in the first flush of enthusiasm over the great discovery, exclaimed, "A new era has opened to the operating surgeon. His visitations in the most delicate parts are performed not only without the agonizing screams he has been accustomed to hear, but sometimes with a state of perfect insensibility, and occasionally even with the expression of pleasure, on the part of the patient. Who could have imagined that drawing the knife over the delicate skin of the face might produce a sensation of unmixed delight! that the turning and twisting of instruments in the most sensitive bladder might be accompanied by a beautiful dream! that the contorting of ankylosed joints should coexist with a celestial vision! If Ambrose Paré and Louis and Dessault and Cheselden and Hunter and Cooper could see what our eyes daily witness, how would they long to come among us and perform their exploits once more! And with what fresh vigor does the living surgeon, who is ready to resign the scalpel, grasp it and wish again to go through his career under the new auspices!"

Not only to Morton, but also to Wells and Jackson, the bitter controversies which grew out of this great invention brought discomfiture,

[1] *A History of the Discovery of Modern Anæsthesia*, by Prof. Henry J. Bigelow.
[2] *History of European Morals*, vol. i. p. 91.

ruin, and untimely death. Wells, becoming the victim of morbid illusions, and finally of violent mania, on January 14, 1848, ended his life with his own hands in a prison-cell in New York, where he had been consigned subsequent to arrest for acts of violence committed in the streets of that city; Jackson, after years of hopeless insanity, died August 28, 1880, in an asylum in Somerville, Mass.; and Morton, stricken with apoplexy, "induced by a publication in behalf of Jackson of a nature to prejudice a subscription then arranged in New York for his benefit" (Bigelow), there died, July 15, 1868, "poor in a cause which has made the world his debtor."

Ether.

Discovery.—This substance is supposed to have been known at least as early as the thirteenth century, as there is some evidence that its existence and leading physical properties were understood by Raymond Lully of Majorca, who flourished during that period. Basil Valentine also mentions a substance having a "subtle, penetrating, pleasant taste and an agreeable smell," which he obtained by the action of oil of vitriol upon alcohol.

The honor of the discovery of ether is, however, usually assigned to the German physician Valerius Cordus, who in the year 1540 described the method of making it and gave it the name of *oleum vitroli dulce.*

Investigations of Frobenius.—For nearly two hundred years following the publication of his formula by Valerius Cordus but little mention of the substance appears in chemical or medical writings; indeed, its mode of preparation had become almost a lost art at the time of Sigismund Augustus Frobenius, M. D., F. R. S., who in a paper read before the Royal Society of London in the year 1730 brought it prominently into notice. In this paper[1] he for the first time applied to the fluid the term "æther," and describes its physical properties as follows:

> "The æther of plants appears to be almost destitute of all gross air. . . . . A little of it poured on the surface of the hand affects it with a sense of cold equal to that from the contact of snow, and blow upon it but once or twice with your mouth, immediately your hand becomes dry. Beware, however, of approaching a lighted candle with your hand thus wet, lest it take fire and burn you. . . . .
>
> "Hence it appears that this æther is both fire and very fluid water, but so volatile that it soon evaporates, and that it is the purest fire, insomuch that if kindled in a thousand times the quantity of cold water, it burns inextinguishably." . . . . "The sense of touch does not manifest the least oiliness or fatness in this æthereal liquor, notwithstanding that it is the true, natural, and only dissolvent or menstruum of all fat, oil, rosin, and gum whatever."

November 18, 1731, Frobenius performed before the Royal Society certain experiments "with his *spiritus vini æthereus* and the phosphorus urinæ," from the recorded account of which the following is extracted:[2]

[1] "An Account of a *Spiritus Vini Æthereus*, with several experiments tried therewith," *Philosophical Transactions*, abridged, 1719–33, pp. 744, 745.
[2] *Phil. Trans.*, abridged, vol. ix. pp. 372, 373.

"He took a solution of phosphorus in the æthereal spirit of wine, which he called *liquor luminosus*, and poured it into a tub of warm water; whereupon it gave a blue flame and smoke, attended with so small a degree of heat as not to burn the hand if put into it.

"He poured some of his æthereal spirit of wine upon a tub of cold water, and set it on fire with the point of his sword, which being first heated a little, he touched with it a piece of phosphorus lodged beforehand on the side of the tub. After the deflagration the water was cold."

Frobenius then showed the now common experiment of burning phosphorus under a glass bell, producing a large quantity of *flores*.

"As the *flores* began to cover the inside of the bell to some considerable thickness, the flame was not seen through so brightly as before, but the whole appeared of a light azure or sky color, which the doctor likened to the formation of the firmament. The *flores* sublimed he likened to snow."

The formula followed by Frobenius in the preparation of ether was not publicly announced until after his death in 1741, when the secretary of the Royal Society, C. Mortimer, M. D., published the following statement concerning it:[1]

"Dr. Frobenius being dead, and some learned chemists in Paris, in Germany, and in Italy having endeavored in various manners and with different contrivances to make this ethereal spirit, I thought it would be acceptable to the curious in England to give them an abstract of the three papers the doctor communicated to the Royal Society concerning his *spiritus vini æthereus*. The first he gave in on Feb. 19, 1729–30, along with what is printed in vol. vii., but was desired by the author not to be published at that time. In this paper he says you must take of oil of vitriol and the highest rectified spirit of wine equal parts by weight, not by measure; that the oil of vitriol was to be poured by little and little into the spirit of wine, because they will grow hot upon mixing; that they should be shaken often, that they may mix thoroughly; then to be digested in a glass retort, and a large receiver to be applied and luted on, lest the subtil spirits should fly away; then distil them in an *athanor* in gentle digestion for three days, and pour back the distilled liquor till the liquor in the recipient appears double or of two sorts. Thus far, he says, Sir Isaac Newton was acquainted with the process. . . . .

"He concludes by telling us that the first part of the process, till one comes to the separation of the two liquors, is mentioned by Caneparius in his book *De Atramentis*, first printed at Venice, and afterward at London; then by the great Mr. Boyle, afterward by Sir I. Newton—that Dr. Stahl and Professor Hoffmann were the first in Germany who knew the first operation from Kunckel, but neither of them brought it to perfection or knew the effect of it. In France, M. Homberg undertook an experiment somewhat analogous to this with sulphur and oil.

"The second paper was communicated on the 12th of February, 1740–41, in Latin, and contains an ample account of the whole process, with improvements and additions; but as the author in his third paper, given in Feb. 19, 1740–41, in English, says that that is the truest and most advantageous process, I shall present it to the reader as follows:

"Take four pounds in weight of the best oil of vitriol, and as much in weight, not measure, of the best alcohol or the highest rectified spirit of wine.

[1] *Phil. Trans.*, 1732–44, vol. ix. pp. 379–381.

"1. First, pour the alcohol in a chosen glass retort; then pour in, by little and little, one ounce of oil of vitriol; then shake the retort till the two liquors are thoroughly mixed, when the retort will begin to grow warm; then pour in more of the spirit of vitriol, and shake it again; then the retort will become very hot. Do not pour in the spirit of vitriol too fast or too much at a time, lest the glass retort, by being heated too suddenly, should burst. You must allow about an hour's time for pouring in the spirit of vitriol, not pouring in above an ounce at a time, and always shaking the retort, till the whole quantity of the ponderous mineral spirit is intimately united with the light, inflammable vinous spirit.

"2. In the next place, examine with your hand the heat of the glass retort, and have a furnace ready, with the sand in the iron pot, heated exactly to the same degree as the retort has acquired by the mixture of the two liquors; take out some of the sand, and, having placed your retort in the middle of the iron pot, put in the hot sand again round the retort, and apply a capacious receiver to it; set it in cold water, and wrap it over with double flannel dipped in cold water.

"Raise your fire gradually, that the drops may fall so fast that you may count five or six between each, and that beside this quick discharge of the drops, the upper hemisphere of your receiver appear always filled with a white mist or fumes; continue this heat as long as they emit the scent of true marjoram.

"As soon as the smell changes to an acid, suffocating one, like that of brimstone, take out the fire, and lift the retort out of the sand, and change the receiver; for all that arises afterward is only a mere gas of brimstone, and of no use.

"If you do not use the greatest precaution the liquors in the retort will run over: the fire must cease as soon as the ethereal spirits are gone over, for there remains behind an *oleum vini*, which is extracted by the force of the acid out of the spirits, which will arise, run over, and often cause explosions.

"The second day, when your glass is cold, infuse the remainder with half as much alcohol, and distil again as before, and you will have the same. The third day again with as much, and proceed as at first: it gives it again. Go on as long as you can obtain any of the ethereal spirit, till all turns to a *carbo;* then separate it, and *alcalize* it with spirits of *salt armoniac* made without spirits of wine, till all effervescence ceases, and distil it once more è balneo marica; so is it ready for experiments."

Modern Chemical View.—The process of Frobenius has, of course, been much simplified and improved, but in all essential principles it remains unchanged. The view taken of the chemical changes upon which the production of ether is dependent has, however, with the progress of chemical science, undergone many important modifications, the theory now generally accepted being that of Williamson, that in the distillation of alcohol with sulphuric acid, acid ethyl-sulphate (sulphovinic acid), and water are first formed, as follows:

$$\underbrace{\left.\begin{matrix}C_2H_5\\H\end{matrix}\right\}O}_{\text{Alcohol.}} + \underbrace{\left.\begin{matrix}H\\H\end{matrix}\right\}SO_4}_{\text{Sulphuric acid.}} = \underbrace{\left.\begin{matrix}C_2H_5\\H\end{matrix}\right\}SO_4}_{\text{Acid ethyl-sulphate.}} + \underbrace{\left.\begin{matrix}H\\H\end{matrix}\right\}O.}_{\text{Water.}}$$

By the continued application of heat in the presence of an additional molecule of alcohol one molecule of ether (ethyl oxide) and one of sulphuric acid are evolved:

$$\left.\begin{matrix}C_2H_5\\H\end{matrix}\right\}O + \left.\begin{matrix}C_2H_5\\H\end{matrix}\right\}SO_4 = \left.\begin{matrix}C_2H_5\\C_2H_5\end{matrix}\right\}O + \left.\begin{matrix}H\\H\end{matrix}\right\}SO_4.$$

Alcohol. Acid ethyl-sulphate. Ether. Sulphuric acid.

The ether thus formed, owing to its superior volatility, passes out of the retort in the form of vapor to be condensed in the receiver, while the sulphuric acid remains ready to enter anew into combination with alcohol as in the first reaction.

Thus, theoretically, a given amount of sulphuric acid could be used indefinitely, but practically its power of etherification is limited to about six times its own weight of alcohol, the chief reason for its failure to act further being found in its dilution by the water formed in the process, and for which it has so great an affinity.

Preparation of Ether by Modern Processes.—To prepare pure ether by modern processes alcohol mixed with a given proportion of sulphuric acid is placed in a retort provided with a suitable condenser and raised to a temperature between 260° and 280° F. The ether distils over, contaminated, however, with a certain amount of alcohol, water, sulphurous acid, and various other products of secondary decomposition. For use as an anæsthetic all these impurities must be carefully removed, for although so commonly known as sulphuric ether, a pure specimen contains no trace either of that or any other acid, the term "sulphuric" being simply in allusion to the acid employed in its preparation.

To effect the necessary purification of the crude distillate it is first agitated with distilled water, which unites with any alcohol present. After a certain length of time the ether will nearly all separate from the water and float upon its surface. It is then carefully poured off, and shaken up in a closely-sealed vessel with lime and chloride of calcium; these free the ether from any remaining traces of water and alcohol and from all acid contaminations. Finally, the ether is subjected to a second distillation. Thus prepared, it constitutes the *æther fortior*, or stronger ether, of the United States Pharmacopœia, the standard of which is a specific gravity not greater than 0.728. It is a colorless, limpid fluid with a characteristic odor, fragrant and penetrating in its quality, and a sweet and pungent taste.

Ether is a solvent of phosphorus, sulphur, iodine, bromine, bromoform, iodoform (sparingly), chloroform, alcohol, oils and fats, caoutchouc, and gutta-percha: it is itself soluble to a limited extent (five parts in fifty) in water.

For inhalation the stronger ether must be employed. Usually, the practitioner can rely upon the drug as sold by responsible firms, but in cases of doubt the specimen should be carefully examined and tested.

Testing Ether.—In testing, a suitable hydrometer will give fairly reliable results as to specific gravity, absolute ether having at 68° F. a specific gravity of 0.710, the *æther fortior* that already indicated; anhydrous ether will not dissolve tannin.

For the freedom of the specimen from alcohol the following test is given in the *Pharmaceutical Proceedings* for 1871–72: it is to add to the ether a small amount of pyroxylin; if this, after standing a few minutes, be not dissolved, the absence of alcohol may be inferred, the presence of a certain proportion of alcohol being essential to the solution of pyroxylin in ether. Crystals of fuchsin will produce a red color with alcohol if it be present in the suspected specimen of ether, while the latter, if pure, will remain colorless.

All acid contaminations may readily be detected, as they redden blue litmus. The sulphur acids, which are those most likely to be present, produce a white precipitate with barium chloride or nitrate. Acetic acid develops a red color with a salt of iron.

If the stronger ether be shaken with an equal bulk of water, it loses from one-tenth to one-eighth its volume. It boils actively in a test-tube half filled with it, and enclosed in the hand, on the addition of small pieces of glass. Half a fluidounce of the liquid, evaporated from a porcelain plate by causing it to flow to and fro over the surface, yields a faintly aromatic odor as the last portions pass off, and leaves the surface without taste or smell, but covered with a deposit of moisture (*U. S.*). The absence of odor in this test is well adapted to establish the freedom of the specimen from fusel oil.

Chemical and Physical Properties.—Ether is an exceedingly inflammable substance, and in the pure state becomes gaseous above the temperature of 95° F. Although so rapidly volatilized, the vapor has a density more than twice as great as that of atmospheric air, so that during its administration by inhalation large volumes of the vapor will sink to the level of the floor, and there remain until diffused in the general air of the room—a result which, owing to the great tension of the vapor, speedily follows. As the vapor is inflammable, and when mixed with air very explosive, lighted lamps and all incandescent substances should, if used at all during etherization, be kept above the level of the patient and operator. Even in pouring ether from one bottle into another caution should be observed, the close proximity of artificial light being dangerous.

Physiological Effects Internally Administered.—The effects of ether internally administered are in most respects analogous to those produced by alcohol. The degree of local irritation which results will, as with alcohol, vary with the amount and purity of the drug. When swallowed without dilution the lining membrane of the stomach becomes congested; there is stimulation of the gastric follicles and an increased outpouring of all digestive fluids, including the saliva. As, however, the digestive ferments are rendered inert through precipitation of their albuminoid constituents, the digestive process is for the time arrested, and chronic etherism, like chronic alcoholism, results in structural degeneracy of the digestive organs and permanent impairment of their functional power.

Owing to the rapidity of its vaporization at the body temperature, the burning sensation which ether at first produces in the mouth, throat, and stomach is speedily succeeded by a sense of coolness. The tension of the vapor and the rapidity with which it is formed usually cause copious eructations, and frequently occasion painful gastric distension. As at low temperatures vaporization goes on less rapidly, it has been recommended that the ether be taken mixed with ice-cold water. Anstie took two and a half fluidrachms of ether suspended in six ounces of a mucilaginous mixture, and, owing to the protective action of the vehicle, with no more uncomfortable local result than a considerable heat at the pit of the stomach. As with alcohol, however, habitual use results in a certain degree of tolerance, and persons addicted to the ether habit ingest even as much as a fluidounce of the substance not only without discomfort, but with apparent enjoyment. The use of ether as an intoxicant is said to have been at one time much in vogue in the north of Ireland.

Like alcohol, ether is a cerebral sedative, but owing to the rapidity with which it is eliminated from the system (chiefly by the lungs), the entire duration of its influence as an intoxicant is, as compared with alcohol, quite limited, usually not exceeding one or two hours. During the period of intoxication the action of the heart becomes intensified; a pleasurable glow, followed by diaphoresis, is felt over the entire cutaneous surface; the face is flushed, the eyes brighten, all the senses are quickened; a disposition to muscular movement is manifested—this, chiefly in accordance with the disposition of the subject, varying in character from mere restlessness to inco-ordination or maniacal violence. The mental perversions usual to the condition of drunkenness speedily appear; ideas become confused and distorted, and speech disjointed, rambling, and incoherent, all ending at last in mere obliviousness, with complete suspension of the intellectual functions and with a greater or less degree of paralysis of the motor and sensory nervous tracts. In all cases the body temperature, at first elevated, becomes reduced, and the reduction will continue during that period of lassitude which follows as the necessary reaction from over-stimulation.

Two drachms and a half of ether, taken by Anstie at 10.35 P. M., had at 10.50 P. M. produced a full, bounding pulse, 104 beats to the minute. "There was decided giddiness, great heat and flushing of the face, and perspiration on the brow; the lips also felt stiff, and there was a pricking sensation in them; the sense of the heart's action was painful, as in an attack of palpitation. The mental condition was one of slight confusion. At 12.30 this feeling of giddiness and confusion had hardly disappeared; pulse 96." At 8 A. M. on the following morning he awoke with headache and nausea, which soon passed off.[1]

From this it would appear that between two and three drachms of ether will produce mildly narcotic effects in an adult. A much smaller amount would doubtless produce a decided influence upon persons of great susceptibility or upon those entirely unaccustomed to the use of stimulants.

As proved by the experiments of Anstie, the constitutional effects of ether may be obtained by its absorption through serous as well as mucous surfaces. The injection of half an ounce of ether into the peritoneal cavity of a large terrier resulted in muscular paralysis of the hind quarters and complete loss of sensibility, while full anæsthesia was obtained from the injection of fifty minims of ether into the peritoneal cavity of a large rat. By the immersion of cutaneous surfaces in ether a certain degree of narcotism may be developed, although this is chiefly local in character, owing to the extreme slowness with which absorption

[1] Anstie on *Stimulants and Narcotics*, p. 332.

into the circulation goes on as compared with rapidity of elimination through the respiratory and other tracts. By direct contact of ether with nerve-tissue a suspension of its functions may be secured. In case the nervous tract experimented upon contains both motor and sensory filaments, the functional power of the latter will first be interfered with; motor paralysis will occur subsequently.

Physiological Effects by Inhalation.—Passing now to the inhalation of ether vapor through the respiratory tract, it will be found that the physiological effects produced by this method of administration differ only in minor details from those just described.

The earliest impressions made by the vapor are upon the olfactory and gustatory senses, these impressions being to most persons disagreeable in character. The taste developed is usually pungent and somewhat bitter, although some observers ascribe to it a fruity sweetness of quality which, in the writer's experience, pertains more to chloroform. As the rapidly-vaporized ether particles impinge upon the mucous lining of the mouth and fauces the temperature of the parts is decidedly lowered, and a sense of cold is communicated to the nerves of common sensation distributed to them.

The functional activity of the salivary glands is increased—a result probably chiefly due to the local action of the ether vapor; although it is claimed by Anstie that he has observed the same effect in many mammalian animals, not only when the anæsthetic has been inhaled, but also when it has been injected into the peritoneal cavity, the rectum, or the stomach. The increased salivary flow is by him regarded as due solely to sympathetic paralysis; but more recent investigation shows that in addition to increased blood-pressure resulting from vaso-motor paresis there is direct stimulation of the secretory nerves of the gland.

Upon partial vaso-motor paresis, too, depends flushing of the face and increased diaphoresis; which effects are produced early in the progress of etherization.

Contact of ether vapor with the walls of the pharynx and the highly-sensitive laryngeal mucous surfaces often proves irritative, and, an impression being thus made upon the superior laryngeal nerve, and by reflex action upon the pectoral and abdominal expiratory muscles, the act of coughing ensues, this movement being often still further incited by a profuse mucous outflow, the result of local hyperæmia and direct stimulation of the mucous follicles of the respiratory tract. These irritative causes also frequently excite to functional activity those sensory and motor filaments of the pneumogastric controlling the act of deglutition, and repeated attempts at swallowing will be made. Fortunately, the power to swallow is usually very persistent, and even when the patient is fully narcotized it is not uncommon to see the act of swallowing automatically performed and the mouth and fauces thus relieved of fluid accumulations.

Sometimes, owing to these reflex irritations, the muscular apparatus concerned in the act of vomiting will be put in operation and an effort be made to void the contents of the stomach.

The violence of these local effects will vary with the nervous susceptibility of the individual; it is also, to a certain extent, dependent upon the degree to which the air is saturated with ether vapor in the earlier stages of the anæsthetic procedure. If the volume of vapor be too highly concentrated, to the exclusion of a due proportion of atmospheric air, a suffocative feeling too will be developed in consequence of the need of the system for more oxygen.

The earlier stages of ether narcosis are marked by a decided increase in the pulse-rate and in the frequency of the respiratory movement, these results being speedily followed by depression to or below the normal standard. The following table, from Anstie, gives the average effects upon these functions in thirty-four cases, twenty-one males and thirteen females, all but three being over the age of puberty, and all free from any discoverable disease of heart or lungs:

	At commencement of inhalation.	At end of first minute.	At end of second minute.	At end of third minute.	At end of fourth minute.	At end of fifth minute.
Average frequency of pulse	74.5	92.7	109.8	110.2	94.3	69.3
Average frequency of respiration . . .	23.0	23.0	24.7	26.3	18.9	15.67

The high average rate of respiration which, as this table shows, was manifested at the commencement of inhalation is explained by Anstie as being due to agitation and alarm on the part of some of the subjects of the experiments—a very usual condition, especially with females. It will be observed that while the rise and fall in pulse-rate and the rate of respiration are coincident, these respective movements are not by any means in the same numerical ratio, the range of increase and decrease in the number of heart-beats being relatively much the greater of the two.

These changes, associated as they are with other functional disturbances kindred in character, have caused a general recognition of the fact that the phenomena of anæsthesia are divisible into two clearly-defined stages—a stage of excitement and a stage of depression.

Effects on the Nervous Centres.—As the inception and progress of these effects are necessarily associated with impressions communicated to the nervous organism, the nature, extent, and sequence of the functional changes there excited will now be considered.

Flourens was among the first to describe them: his view was that the great nerve-centres are narcotized in the following order and with the following results: First, the cerebrum, resulting in loss of intelligence and consciousness; second, the cerebellum, with loss of its power of "equilibration" or co-ordination of movement; third, the spinal cord, with loss of its power of receiving sensory impressions and of initiating movements; fourth, the medulla oblongata, with paralysis of the respiratory and circulatory functions.[1]

[1] See *Comptes rendus de l'Académie des Sciences*, séances des 8, 22 février et 8 mars, 1847, t. xxiv. pp. 161, 253, 340.

The theory promulgated thus early in the history of anæsthesia has not been materially modified by the observations of subsequent experimenters, except in so far as relates to the operation of anæsthetic agents upon the sympathetic nervous system, concerning the structure and functions of which so much light has been gained through the labors of later physiologists.

Anstie was the first to call attention to the fact that the sympathetic nervous system is the earliest to feel the influence of the anæsthetic, this being indicated by the flushing of the face, increased salivary secretion, etc., already alluded to. But while it is the first to receive the impression, it is the last to succumb to the narcotic power of the agent employed, so that even after paralysis of the medulla oblongata, and consequent cessation of the respiratory act and of perceptible movement of the heart, certain processes of vegetative life, such as intestinal movement, arterial contraction, etc., over which the sympathetic presides, may still go on. It would, then, appear that its partial paralysis is the first, and its complete paralysis the last, in the sequence of effects set up in the nervous system by ether and other allied drugs.

Nature of Ether Narcosis.—Anstie's peculiar views in regard to narcotism led him to reject the idea that stimulation, in the common acceptation of the term, has any part in ether narcosis, he claiming that rapidity of movement in heart and lungs is an evidence not of strength, but of weakness—a conclusion not confirmed by the later developments made by the sphygmograph and other instruments of precision. While the physiology of the subject is not by any means definitely determined, a rational explanation of the known phenomena would seem to be that the ether vapor, entering the circulation through the walls of the capillary blood-vessels which surround the pulmonary vesicles, produces, primarily, by contact, a partial local paralysis of the vaso-motor branches of the sympathetic system distributed to the walls of the pulmonary vein. The tonicity of its walls being thus diminished, an increased amount of blood is admitted through it to the left ventricle of the heart, whence a portion enters the coronary arteries to pass directly into the substance of the heart itself. As the ether-laden blood enters the coronary arteries their vaso-motor nerve-fibres also undergo partial paralysis, and their walls a loss of resisting power to the impact of the vital current, so that the muscular fibres of the heart and its motor ganglia receive the stimulus of an increased supply of blood; under which stimulus it is for a time incited to greater activity. As its pulsations increase in force and frequency larger amounts of blood are sent through blood-vessels—which, in their turn, become dilated—to all the great vital centres and to all organs and tissues of the body, their functional power, in consequence of such increased stimulation, undergoing for a brief period a greater or less degree of exaltation.

Such are really Nature's agencies for hurrying through the system and expelling through her eliminative organs and tissues the offending agent. And in the case of so volatile a substance as ether these means would be ample for the purpose were the administration of the drug at once suspended: then the stage of general depression, except as the result of the usual reaction after stimulation, would not be reached;

but as increased volumes of ether vapor continue to pour into the circulation, its very rapidity of movement becomes tributary to the power of the toxic agent. Elimination cannot keep pace with supply. The pulse and respiration diminish in force and frequency; the great ganglionic centres of the nervous system begin to yield; the very citadel of life totters, and will fall unless the invading forces be held in check or withdrawn.

Phenomena of Etherization.—It is evident that the minor physiological effects already described as incident to ether narcosis are directly dependent upon these functional disturbances in the respiratory, circulatory, and nervous systems. This is equally true of those now about to be considered.

As the result of an increased supply of blood to the brain there is a momentary stimulation of the intellectual functions: ideas as they are formed are not always coherent, but they are developed with greater rapidity than in the normal state, and are dominated by a pleasurable exhilaration. These effects are, however, soon followed by giddiness, a tumultuous rush of undefined impressions, ending in unconsciousness; which latter condition comes on at a very early period after the full inhalation of ether begins.

Preceding the loss of consciousness a sense of warmth, due to the rapidity of the circulation and to the capillary hyperæmia, will be perceived. This is soon followed by a faint numbness and tingling, caused by the partial paralysis of the superficial sentient nerves, these being among the earliest indications of approaching anæsthesia. As the motor nerves do not yield so readily to the narcotic influence, muscular movement is still stimulated, and, although lacking co-ordination, is frequently quite active, and generally directed to an avoidance of the anæsthetic or to an effort to combat the physical restraint exercised by the operator. After the loss of consciousness it often takes on a more violent form and becomes convulsive or tetanic in character. This form of muscular movement is most pronounced in male adults, especially those in whom the muscular system is strongly developed as the result of labor or exercise. Dr. Snow states that the patient in whom, in his experience, these symptoms were most violent was a celebrated harlequin attached to one of the London theatres. The cessation of these movements and the complete relaxation of the muscular system mark the stage of complete narcosis, in which, not only intellection but movement and sensation are suspended.

Effects on the Eye.—The ordinary effects of anæsthetics upon the eye are somewhat variable. At the very beginning of the administration of the anæsthetic, or even before, the pupil of the eye will be frequently found dilated. This dilatation, however, with advancing narcosis disappears, and the pupil at the same time manifests a greater or less degree of insensibility to light, so that it contracts very slowly when the eyelid is lifted for purposes of examination. At this time, too, the eyeballs will be found slightly divergent and turned upward to a considerable degree. Notwithstanding this condition of impassivity of the pupil under the stimulus of light, it gradually contracts, and so remains except in extreme narcosis, when there is a condition of slow dilatation, the degree of myosis depending upon the extent to which the narcotic influence has been carried. With the removal of the anæsthetic the pupil gradually returns to its normal state, but during its return is subject to secondary dilatations.

An explanation of the precise physiological significance of these movements must of course be offered, subject to the same incertitude which still clouds the mechanism of the movements of the iris in the normal state. Upon this point the view most generally accepted is, that narrowing of the pupil is due to the contraction of the circular muscular fibres, or sphincter, of the iris which directly surround the pupillary orifice, this muscle being under control of the cerebro-spinal system through the oculo-motor nerve. Stimulation of this nerve, through its normal reflexes or otherwise, produces contraction of the sphincter, and consequent narrowing of the orifice of the pupil. Paralysis of the nerve produces an opposite condition.

The existence of radiating muscular fibres is now generally admitted by anatomists, their contraction directly antagonizing that of the circular muscular fibres, and they being under control of the dilating branches of the sympathetic contained in the long ciliary nerves. The sympathetic may, then, be regarded as furnishing the dilating, the cerebro-spinal system the contracting, nerve-force of the pupil.

The theory of Raehlmann and Witkowsky[1] concerning the nature of the pupillary changes which occur during anæsthesia is based upon their own observations, as well as upon the experimentations of earlier and contemporaneous physiologists, and is, that dilatation of the pupil is not alone dependent upon the influence of light and the movements of accommodation, but that it may be the result of psychic influences or follow certain sensory impressions made from without; which impressions, communicated to the brain, and thence to the medulla oblongata, and from there to the sympathetic nerve-fibres of the iris, produce, through contraction of its radiating muscular fibres, the effect in question.

To this sequence of influences may be attributed the dilatation observed before the inhalation of the anæsthetic begins, the psychical impression upon the brain of the patient being that of dread of the anæsthetic process or of the impending operation; in other words, the pupil dilates through fear.

Or when inhalation has begun the sympathetic may be influenced through the irritant effect of the ether vapor upon the nerves of special or general sensation distributed to the respiratory tract. It is of course evident that as the brain and sensory nerves, which are speedily anæsthetized, become incapable of receiving and communicating these psychic or sensory impressions, the sympathetic ceases to be influenced by them, and the motor oculi resumes its sway.

The insensibility to light exhibited by the iris during anæsthesia is, of course, due to partial paralysis of the motor oculi, which for this reason responds but slowly to the stimulus it ordinarily would receive, and does receive, through the optic nerve until the functions of the latter, too, are suspended.

[1] See Kappeler, *Anæsthetica*, pp. 59, 60, Stuttgart, 1880.

As with advancing narcosis paralysis of the motor oculi deepens, the sympathetic—which, as has been seen, retains a measure of functional activity after the reflex irritability of the cerebro-spinal system has been obliterated—continues to operate upon the dilator muscles with a power greater proportionately than the resistance of the constrictors, pupillary expansion being the result.

Returning consciousness brings with it a reversal of these phenomena. As paralysis of the motor oculi diminishes, its power of producing pupillary contraction is resumed, although this power is often antagonized by reflex action upon the ciliary or dilator branches of the sympathetic from a brain again aroused to consciousness and capable of influencing the sympathetic system with the impressions, generally painful, which attend the awakening from an anæsthetic sleep produced for surgical purposes.

Effects on Temperature.—Although at the beginning of etherization there is a slight temporary increase in surface temperature, caused by the turgescence of the cutaneous capillaries, the actual body heat is lowered very shortly after the inhalation of the anæsthetic begins. This is due to the retardation of tissue-changes consequent upon the presence of the anæsthetic in the blood and the diminished amount of oxygen admitted to the circulation.

In the carefully conducted experiments of Kappeler[1] upon twenty cases the minimum fall in temperature, as indicated by a thermometer fixed and retained in the rectum, amounted to 0.3°, the maximum to 1.5°, and the mean to 0.68° C.; or, excluding from the calculation those cases, eight in number, in which there was an abnormal temperature as the result of fever at the beginning of the experiment, an average fall in temperature of 0.52° C. was observed. In only three cases was there a slight increase (0.1° to 0.2°) of body heat at the beginning of inhalation, this increase being in each case associated with strong muscular movements. In thirteen cases the body temperature reached its original height during the course of the same day, while in seven cases, although there was an increase from the lowest point reached during inhalation, the temperature failed to attain its original height for a period varying from an hour and forty minutes to six hours and a half after the inhalation of the ether ceased. The fall in temperature began in thirteen cases ten minutes, in five cases fifteen minutes, and in one case twenty minutes after the commencement of inhalation. In one case this point was not noticed. Without exception the greatest depression in temperature was observed in those cases in which the ether had been exhibited in largest quantity and in which the deepest narcosis had been produced.

Stages of Anæsthesia.—Various authors have endeavored to group these physiological effects into a series of progressive degrees or stages of narcotism. Dr. Snow, one of the earliest writers upon the subject, made four degrees,[2] the first degree ending with loss of perfect consciousness; the second degree ending with complete loss of consciousness; the third degree terminating with the cessation of muscular spasm and all voluntary movement; the fourth degree being marked by com-

[1] Kappeler, *Anæsthetica*, pp. 168, 169. [2] Snow on *Anæsthetics*, p. 37.

plete muscular relaxation and loss of sensibility. Sansom[1] makes three stages, as follows: "A *first stage*, SOPOR (perversion of sensibility); a *second stage*, STUPOR (abolition of sensibility); a *third stage*, STERTOR (muscular relaxation)." Kappeler[2] makes two stages: first, a stage in which consciousness is retained; second, a stage in which consciousness is lost—the first stage embracing simply aberrations in the domain of the special senses, disturbance of the intelligence, diminution of general sensibility and of the perception of pain, widening of the pupils, quickening of the movements of the heart, and irregularity of the movements of respiration; the second stage embracing all subsequent phenomena up to the complete loss of sensibility.

From this brief review of the few among many schemes of classification it is evident that although the phenomena of anæsthesia follow each other in certain apparent sequences, these are so involved, the one within the other, that it is not easy to define their beginning or their end. The fact, however, is apparent that the most significant and clearly-defined phenomenon associated with the inception of the anæsthetic influence is that of universal functional excitation, this being quickly followed by the partial obtunding of sensation and by suspension of conscious cerebration, excitation of the motor system still for a time continuing; and that at the end of the chain of effects is universal functional depression, with continuance of unconsciousness, and complete abolition of sensation. All intermediate or succeeding phenomena are associated with one or the other of these conditions, and, logically, must be classified with them.

From this point of view there are but two stages in anæsthesia: First, the stage of functional excitation, during the progress of which sensation is gradually obtunded and consciousness lost, this stage fully terminating only with the cessation of muscular spasm or rigidity; second, the stage of functional depression, in which the voluntary muscular system is relaxed and sensation abolished.

For convenience of description, however, the author prefers the classification of T. Lauder Brunton, who divides the action of anæsthetics into four stages, as follows:

1st. The stimulant stage;
2d. The narcotic and anodyne stage;
3d. The anæsthetic stage;
4th. The paralytic stage.

Narcosis carried only to the second stage of this classification is for anæsthetic purposes incomplete; narcosis carried to the fourth stage is excessive; and, as will be seen, either insufficiency or excess is in surgical operations dangerous.

CONDITIONS CONTRAINDICATING THE USE OF ANÆSTHETICS.

In all cases the patient should be subjected to a careful physical examination before being permitted to inhale the anæsthetic, because, while there are few conditions which absolutely interdict the use of ether, assuming that surgical interference is necessary, there are many

[1] *Chloroform, its Action and Administration*, p. 199.
[2] *Anæsthetica*, p. 42.

which, if known, would make obligatory upon the operator the exercise of a more than usual amount of care.

Ether is contraindicated in cases of cerebral congestion or where the existence of tumors or abscesses in the brain is known or suspected. In cases of extreme fatty degeneration of the heart ether should be given with great caution, and the same is true, although not to the same degree, where disease of the cardiac valves exists. The chief toxic force of ether is expended not so much upon the heart as upon the respiration; and all conditions of the lungs or air-passages obstructive of the respiratory function increase the liability to dangerous complications during the inhalation of ether vapor. For this reason the existence of acute bronchitis would be an unfavorable condition, as well as for the reason that the inflammation would probably be intensified by it. So, too, emphysema of the lungs, œdema of the glottis, and enlargement of the tonsils are sources of danger during anæsthesia just to the degree that they interfere with normal respiration. Given a patient already in a condition of partial asphyxia from either of these causes, and it would be hardly permissible that his supply of oxygen should be still further curtailed by substituting ether vapor for atmospheric air.

In the cancerous diathesis there seems to be a more than average danger attending the use of ether, and no inconsiderable percentage of the recorded fatalities under etherization have been in cases in which the operation required was for the removal of cancerous growths. Structural degeneracy of the kidneys, too, as in Bright's disease, has been found a condition peculiarly unfavorable for the administration of ether.

Shock.—The existence of that peculiar depression of the vital powers known as "shock," which so often follows the infliction of severe injuries, is by many surgeons regarded as contraindicating the use of anæsthetics, and where immediate operative interference is not demanded by the nature of the injury there can be no question as to the advisability of delay until reaction has occurred; but in many instances the pain arising from the presence of lacerated tissues, as in a crushed and partially severed limb, would of itself cause a persistence of shock, and make an immediate operation imperative; as, too, would persistent hemorrhage not to be controlled without the use of the knife. Ashhurst[1] advises that under such circumstances an operation should not be performed if the temperature of the patient has fallen below 96° F. If, however, the operation is the patient's only chance for life, even this evidence of extreme depression would hardly justify the surgeon in withholding his aid, however great the danger of death under the knife, and however reluctant he may be to assume the possible odium of such a misadventure. Assuming that under these conditions surgical interference is to be resorted to, the patient's chances of survival would be decidedly promoted by the use of ether; without it the renewed injury to tissue and the pain of the operation would intensify shock; with it, not only is pain prevented, but frequently the stimulant effect of the ether vapor sets up a process of reaction, and thus directly contributes to the patient's safety. The statistics presented

[1] *The Principles and Practice of Surgery*, p. 138.

by Sir J. Y. Simpson[1] show that amputation of the thigh performed in some of the leading hospitals of Europe before the introduction of anæsthetics was followed by an average mortality of 44 per cent., while the same operation performed upon anæsthetized patients was attended by a mortality of only 25 per cent.

Operations upon the teeth and associated tissues are often excruciatingly—and in certain conditions of the system dangerously—painful in character. That fatal results may follow such operations in consequence of reflex impressions made through the fifth nerve upon vital ganglia is a well-established fact. A formative alveolar abscess, with its train of possible complications, such as pyæmia, erysipelas, maxillary necrosis, trismus, etc., may occur in patients whose physical condition is such that they are neither fitted to endure the suffering incident to the full evolution even of the normal process of suppuration and discharge, nor able, without an anæsthetic, to bear the shock of such surgical measures as may be required to bring those processes to an earlier and perhaps safer termination. To these and all analogous conditions the general principles just set forth are fully applicable. When, however, in cases not favorable for the use of anæsthetics the necessity for a severe dental operation can for the time be postponed by the use of palliative measures, that course should by all means be adopted. This is especially true in cases of advanced pregnancy. The possible oxytoxic effect of any anæsthetic agent must be borne in mind, and if practicable the operation be postponed until the pregnancy has terminated.

The methods of placing the patient safely under the anæsthetic influence, the physical manifestations by which the progress and safety of the procedure may be determined, and the means by which dangerous complications may be antagonized, now claim consideration.

The Anæsthetic Procedure.

Mode of Administering Ether.—Attention has already been called to the physical and chemical properties of this substance, and to the necessity for avoiding the use of an impure or imperfectly rectified article.

Inhalers.—In order that the ether as it volatilizes may be carried into the respiratory tract upon the inflowing air-currents, the use of some form of inhaler to hold the liquid and, in a measure, confine its vapor is imperative. As already stated, that originally used by Morton was a glass flask with a tube, this being subsequently modified by the addition of valves.

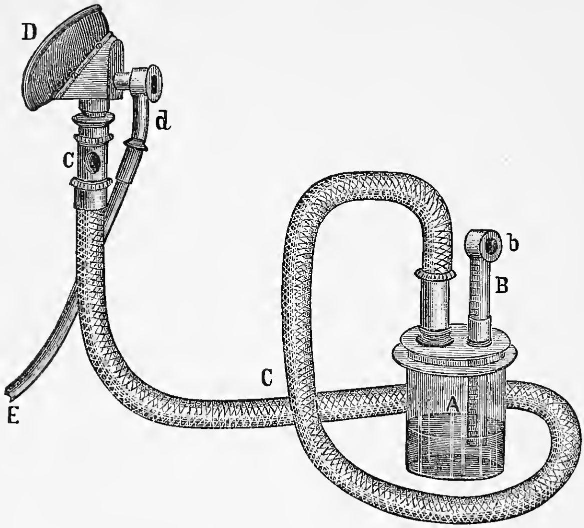
A form of inhaler somewhat allied to this in principle, although much modified in structure, is that of Hawksley, seen in Fig. 1. "It consists of a glass jar A, which will contain ten ounces of ether. The tube B, which contains a valve opening inward, is graduated in order to measure the amount of ether used. The elastic tube C connects the ether jar, A, with the mouthpiece D, and has near the latter a sliding valve (C) for the dilution of the ether vapor with atmospheric air. An

[1] *Anæsthesia*, p. 105.

expiration valve (*d*) and the tube E conduct the expired air out of the proximity of the operator."

Such forms of apparatus are, however, all unnecessarily complicated; valves, tubes, and mouthpieces are difficult to keep clean, and are con-

Fig. 1.



stantly liable to derangement. Inhalers which entirely dispense with these adjuncts are much to be preferred. One much favored by many is that of Dr. Allis (Fig. 2). It consists of an open framework arranged

Fig. 2.

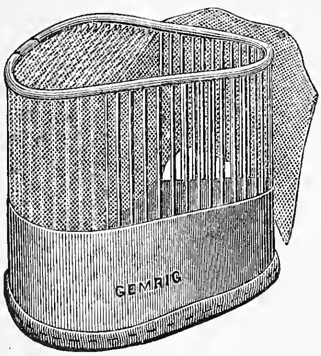
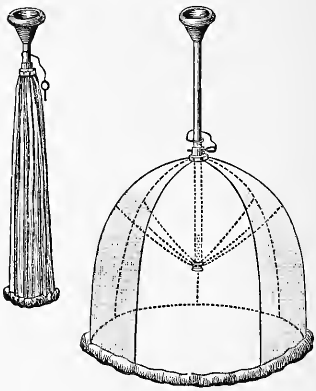


Fig. 3.



to support strips of muslin placed at short distances apart, upon which strips the ether is continuously dropped until anæsthesia is produced. This inhaler is eminently safe, inasmuch as it permits of the fullest possible admixture of air with the ether vapor. It is, however, a somewhat wasteful instrument, as in order to charge such large volumes of air with sufficient ether vapor to produce full anæsthesia it is necessary to use large amounts of the drug.

The inhaler of Dr. Barr (Fig. 3) is not open to this objection. It consists of an open framework made very much after the manner of an umbrella frame. The framework is covered with impermeable rubber cloth, and its interior is lined with a cone of Canton flannel, which may be readily removed when soiled. The ether is dropped into a small funnel placed at the top of the frame: from the funnel the ether passes by a tube to the interior of the inhaler, where it drops upon the Canton flannel lining, from whence it vaporizes.

The simplest form of inhaler, however, is the best. Such a one can be readily extemporized by making from a stiffly-starched towel a hollow cone, and placing in the interior a hollow sponge slightly moistened in warm water, upon which the ether may be poured; or a cone more impervious to the ether vapor may be made from a newspaper, a soft napkin or towel, in lieu of a sponge, being folded up with it on its inner surface. These extemporized inhalers have the advantage of convenience, as the materials for making them are always at hand, and of cleanliness, as after one using they may be discarded. Some surgeons, however, prefer a cone made of felt or leather and lined with a porous fabric for the imbibition of the liquid ether. However made, the base of the cone should be large enough to cover the mouth and nose, but should not be so closely adapted to the face as to exclude atmospheric air. The apex it is well to leave open.

Preparatory Treatment of the Patient.—In all cases in which a severe surgical operation is to be performed it is desirable that the patient should be placed in the best possible condition for the reception of the anæsthetic and for recovery from the effects of the operation. Patients suffering from diseases of malnutrition, anæmic subjects, and those weakened by the effects of scrofula, syphilis, cancer, or other of the cachexiæ, should, when time permits, receive careful nutritive treatment, such articles of food being given as are most nutritious and most easily assimilated, and such medicines being administered as are restorative in character and directly promotive of constructive metamorphosis. By thus building up the system and strengthening the vital powers of the patient previous to the operation he will be much better fitted to endure its severities. In any case violent depletory measures are not to be thought of. While it is always desirable that the bowels should not be loaded with fecal matter, harsh purgation is not needed: a gentle laxative is all that is usually required, this, possibly, to be assisted by a purgative enema. By the use of such agencies the extreme depression so often following the use of violent cathartics will be avoided. The purgative selected should be given so that its full effect will have been accomplished four or five hours before the intended operation. In operating upon the rectum, however, surgeons usually prefer, in addition to a full purgation, to give a purgative enema about an hour before operating. The bladder, too, should be empty or nearly so, and the stomach should contain no food, solid or liquid. To this end the patient should not partake of food for at least four or five hours before the time appointed for the administration of the anæsthetic, and, as under the influence of the mental emotions excited by apprehensions of the approaching ordeal the digestive process is often seriously retarded, it is advisable that very hearty food, such as solid meats, cheese, hard-boiled eggs, and the coarser vegetables, should be avoided during the twenty-four hours preceding the operation. Unless these precautions are observed there is danger that undigested food in the stomach, being ejected during the vomiting which so frequently occurs in the earlier stages of anæsthesia, may at the moment of ejection be drawn into the trachea by one of the violent inspiratory efforts usually following emesis, and so fatal strangulation follow—a result quite certain to ensue if anæsthesia has advanced sufficiently far to suspend the action of those reflexes through which in the normal state the foreign substances might have been expelled from the respiratory passages. For analogous reasons artificial plates and all other foreign bodies should be removed from the mouth.

Abstinence from food is required, not only for the reason here given, but because the presence of food in the stomach, and its consequent distension, necessarily encroach upon the thoracic cavity, and thus interfere with that highest possible freedom of respiratory movement so essential to the safety of the anæsthetic state.

Dr. Agnew has called attention to the fact that the rule here laid down is doubly imperative where an operation is to be attempted for the relief of ankylosis of the lower jaw. He says:[1] "I have seen a person from inattention to this point wellnigh perish by reason of the surgeon's inability to get anything into the mouth to clear out the pharynx, which had become obstructed by material rejected by the stomach while under ether."

The deprivation of food here insisted upon is not inconsistent with those measures for the promotion of nutrition previously recommended: four or five hours is not an undue interval between meals; and the fact must be borne in mind that it is not the undigested food in the stomach, but that which has undergone digestion and assimilation and has entered the circulation, which ministers to the nutrition of the patient and stimulates his vital energies.

Were it not for incidental inconveniences an early morning hour, before the patient has breakfasted, would be in the highest degree favorable for the anæsthetic process. The stomach is empty, but no faintness is experienced because the usual meal-time has not passed; refreshed by rest and sleep, the patient is at his best and without sufficient time for much brooding over the ordeal before him. Mr. Woodhouse Braine, a London "anæsthetist," recommends this hour, and states that Sir James Paget was in the habit of choosing it for his operations, and that he has "frequently met him far on the other side of London at 8 and 8.30 o'clock."[2]

Alcohol in Shock.—So far as the introduction of liquid substances into the stomach is concerned, the general rule is, in conditions of shock, often violated by the free administration of alcoholic stimulants but a short time previous to the beginning of the anæsthetic process; indeed,

[1] Agnew's *Surgery*, p. 282, vol. ii.

[2] *The Journal of the British Dental Association*, Dec., 1884.

many surgeons habitually adopt this practice in all cases in which there is any evidence of depression of the vital powers. Whatever may be the merits of, or necessity for, this practice, the fact must not be lost sight of that the presence of large amounts of alcoholic stimulants in the stomach—and in cases of shock they are often administered in inordinate amount and with unreasoning frequency—is subject to the same dangers pertaining to the presence of other substances. In the act of vomiting, fluids as well as solids may be drawn into the trachea, and cannot fail to embarrass the respiration to a serious extent, if not beyond all power of recovery. In all ordinary cases where ether is to be used the writer regards the giving of alcoholic stimulants as uncalled for, but in shock the administration of from half-ounce to ounce doses of whiskey or brandy is quite a general, although not a universal, practice. In the present state of our knowledge concerning the true nature of the vital depression in question, and of the rôle which alcohol really plays in the animal economy, the practice can hardly be said to rest upon other than an empirical basis, and a closer insight as to the physiological relations of the subject may very materially modify existing rules of practice. All that can at present be said with certainty is that in conditions of great depression alcohol produces a temporary excitation, which, if it is not the index of an absolute increase of vital energy, is at least an effect which closely simulates it. It may, however, be questioned whether this effect might not be more surely and safely obtained by other agents, such as ammonia, or by a cardiac stimulant, such as belladonna. This, however, will largely depend upon habit or constitutional peculiarity: in many cases brandy appears to be better borne by the stomach and to produce a more decided reaction than any other agent. Some practitioners have obtained excellent results from subcutaneous injections of ether, and very many habitually resort to hypodermic injections of morphia in doses of from a sixth to a quarter of a grain.

Maintaining Temperature in Shock.—Whatever method of medication may be resorted to, the temperature of the body must be maintained. This usually falls with the failure of the circulation incident to shock, and the tendency must be antagonized by friction or by sinapisms to the inside of the thighs, to the wrists, or to the chest and abdomen. The direct application of artificial heat should be resorted to. This can best be accomplished by placing bottles of hot water, heated bricks, etc. to the feet and other portions of the body, or by placing upon the chest and abdomen relays of flannel cloths wrung out of hot water. Rectal injections of water as hot as can be borne are also salutary, and the enemata can at the same time be made stimulant in character by the addition of brandy, ammonia, or turpentine.

Venesection.—Owing to the fact that in cases of death from shock the right side of the heart and the great venous trunks are found distended with blood, venesection has sometimes been resorted to, and with apparently beneficial effects. A writer on the subject[1] recommends that "in such cases the superficial veins of the neck should be examined, and if

[1] William Scovell Savory, F. R. S., in Holmes's *System of Surgery*, p. 154, vol. i.

distended the external jugular should be opened. This treatment," he says, "is sanctioned both by reason and experiment." Where large amounts of blood have already been lost as the result of surgical injury, this practice would certainly be inadmissible, and in the present state of public opinion as well as of professional sentiment concerning venesection he would be a bold man who would resort to such a procedure.

PREPARATION OF THE PATIENT.—Attention to the condition of the clothing is an essential part of the preparation of the patient for the inhalation of an anæsthetic. Under no circumstances should the wearing of garments which in the slightest degree impede the respiratory movements or at any point obstruct the circulation be permitted. Tightly-fitting shoes or garters should be removed, as they to a greater or less extent obstruct the venous circulation, and thus in a measure prevent the free return of the blood from the lower extremities to the heart. Collars should be removed, neckbands and waistbands loosened, and all garments covering the chest and abdomen be so arranged as to give full play to their normal movements during the respiratory act. Stays or corsets are, of course, entirely inadmissible, and any elaboration of toilet is in the highest degree objectionable. The garments worn either by males or females should be few in number and simple in character, so that in case of emergency they can be readily removed. In texture and weight they should be adapted to the season of the year and the temperature of the apartment, the importance of maintaining the bodily heat of the patient being always borne in mind.

Temperature of the Room.—The temperature of the apartment in which the anæsthetic is to be administered will have an important bearing upon the rapidity and completeness with which anæsthesia is attained, because, as has been shown by Snow,[1] the warmer the air the more rapidly will ether vaporize and the more perfectly will the air become saturated with the vaporous particles, so that too low a temperature is to be avoided, not only because it will reduce the bodily heat of the patient, but because it will interfere with the volatility of the anæsthetic. At 40° F. air will take up only 27 per cent. of ether vapor; at 60° F., 40 per cent.; at 70° F., 58 per cent.; and at 80° F., 71 per cent. These figures were obtained by Dr. Snow under conditions which permitted the full saturation of the air with ether vapor—conditions which rarely if ever occur in actual practice when the ordinary inhaling apparatus is used; but they clearly indicate the fact that in a room having a temperature so near the freezing-point as 40° F. very little ether would be evaporated, the anæsthesia being correspondingly imperfect, while at higher temperatures ether would be vaporized with great rapidity and the anæsthetic process be correspondingly rapid and effective. These theoretical deductions have been amply sustained by practical experience, and a temperature of from 70° to 75° F. may be regarded as the most favorable for the production of the anæsthetic state when ether is the agent employed.

It may be here remarked that not only should the room in which the anæsthetic is given be sufficiently warm, but a like care should be observed

[1] *Anæsthetics*, p. 347.

in regard to the room in which the patient is placed after the operation is completed.

Position of the Patient.—As a general rule, the patient should be placed in the supine position, with the head and shoulders but slightly raised, the head being in line with the long axis of the body and neither bent forward nor thrown backward. Braine[1] recommends "lying on the side, with one hand and forearm under the pillow, the shoulders being slightly raised and the neck a little bent, so that the saliva, which is always secreted in large quantities, may run from the lower corner of the mouth and not be swallowed." "This salivary secretion," he states, "readily takes up ether vapor, and if swallowed is sure to produce vomiting." While this position may be advantageous in certain cases, it somewhat cramps the respiratory movements, and the patient can breathe much more freely and deeply when placed upon his back as above described.

Recumbency in every practicable case should, however, be insisted on, so that as the heart-impulses weaken under the toxic influence of the anæsthetic the flow of the blood-currents to the brain and vital centres may be favored by gravity, and the circulatory apparatus be thus in a measure relieved from strain—a strain so great as sometimes to result in cardiac failure and collapse. This danger is not so imminent when ether is employed, and in operations in the mouth or upon the jaws the more convenient semi-recumbent position may sometimes be permissible; but when chloroform is used, so great is the danger of heart paralysis that full recumbency is imperative. The enormous percentage of deaths from chloroform in dental operations is doubtless largely due to neglect of this rule. With either agent it is a neglect for which there is no excuse. All modern dental chairs permit of the recumbent attitude on the part of the patient, and there is ordinarily in the position no insuperable mechanical obstacle to the extraction of the teeth: even if such an obstacle exists, the patient can readily be raised to the required posture at the moment of extraction, and then be as readily replaced in the recumbent attitude.

Assistants and Witnesses.—Ether should never be administered for surgical purposes without the presence of one or more assistants to the operator. The number required will vary with the nature and gravity of the operation and other attendant circumstances. In capital operations at least two assistants are usually required, one to control the circulation in the part to be operated upon, and one to administer the anæsthetic. This number is certainly desirable both for safety and convenience, although in emergencies, such as often arise during the progress of a war, the surgeon may be compelled to perform the most formidable operations without skilled aid. In dental practice the presence of an assistant or assistants is equally imperative—firstly, because when ether is used the patient may become restive and require the exercise of great physical strength for his restraint; secondly, because dangerous complications may arise demanding the immediate adoption of certain methods of treatment which the operator, unaided, would be unable to execute; and, thirdly, for the reason that the assistant is a witness to the

[1] *Op. cit.*

general conduct of the operation—a witness whose testimony would be invaluable were its regularity or skill called in question; and for the security of all concerned the presence of a third party, if not as an assistant, then as a witness, is indispensable. Especially imperative does this become when a female is to be anæsthetized. It is a physiological fact, now well established, that the nerves of special and general sensation in the genito-urinary tract are among the last to yield to the influence of anæsthetic agents, so that impressions made upon other portions of the nervous system are by the patient referred to these still sensitized surfaces, under which stimulus erotic dreams of a most vivid type are often the result: so vivid, indeed, are these impressions that the protestations of a whole roomful of friends and kindred have failed to convince the patient that she had not been lasciviously approached during her anæsthetic sleep. So many cases of this kind are now on record,[1] so many stainless reputations have been assailed as the result of this curious psychical phenomenon, that the surgeon hardly deserves commiseration who out of neglect of so simple a precaution as the insistance upon the presence of a witness or witnesses becomes the victim of a baseless charge of this kind.

The assistant selected as administrator of the anæsthetic should be skilled in the mechanical details of the process and familiar with the line of physiological effects to be produced: too often this important process is entrusted to a callow student or an uninstructed nurse. The assistant should confine his attention strictly to the progress of the anæsthesia and the condition of the patient, not allowing his attention to be distracted by a desire to watch the details of the operation about to be performed.

Final Arrangements.—All instruments and appliances likely to be required during the progress of the operation should be carefully and conveniently arranged before the administration of the anæsthetic begins, but there should be no ostentatious display of instruments. In dental operations the tooth or teeth to be extracted should be examined, and the forceps or other instruments best adapted for the case in hand selected and placed within convenient reach of the operator, but out of sight of the patient. Both operator and assistant should avoid all flippancy of conduct or of speech, and carefully refrain from any act likely to produce disquiet in the patient or disturb his or her mental equipoise. However trifling the ordeal through which the patient is about to pass may appear to the operator, it assumes in the mind of the patient a far greater magnitude, and indeed is never without its dangers: by manners grave but gentle and assured much can be done to quiet apprehension and strengthen confidence.

No administrator of anæsthetics can be regarded as perfectly equipped for his task who has not provided himself with stimulants necessary for use in cases of syncope. Among these must be included a well-constructed electric battery. A tracheotomy-tube and instruments necessary for performing the operation should also be at hand.

ADMINISTRATION OF THE ANÆSTHETIC.—The patient being fully prepared, the administration of the anæsthetic may begin. Assuming

[1] See article on "Dental Jurisprudence," Vol. III.

that the ordinary cone-and-sponge inhaler is to be used, about half a fluidounce of ether is poured upon the sponge, additional amounts being from time to time added as required; the inhaler is placed over, but not upon, the mouth and nostrils of the patient, who with a few reassuring words is directed to take full and deep inhalations. With timid or nervous persons previous instruction in this is advisable. Silence should at this time be observed in the operating-room, as conversation distracts the attention of the patient and is likely to prolong the period of consciousness. Owing to the irritant effect of the vapor and the suffocative feeling produced, these first inhalations are taken with great reluctance: the patient will frequently attempt to move the face from beneath the inhaler or to push it away with the hands. These efforts should be gently but firmly restrained, and the inhaler be retained in position, care being taken to allow enough space between it and the face to permit the passage of ample volumes of atmospheric air. The fact cannot be too much emphasized that without air there is no safety for the patient, and that the guiding principle of the administration is not the pouring into the air-passages of the largest amount of concentrated ether vapor in the shortest possible space of time, as one might pour the liquid ether through a funnel into a bottle, but a veritable dosage, through the respiratory tract, of vaporous ether in such a degree of solution or attenuation in atmospheric air as shall render it least irritant to, and at the same time most readily absorbable by, those surfaces through which it must pass by osmosis into the circulation. Too concentrated a dosage by the lungs, as by the stomach, may defeat its own end.

When the administration of the anæsthetic is pushed with any degree of boldness and skill, consciousness will very speedily be abolished, this effect coming on very early in the process, and for a time the patient will inhale the vapor more freely and naturally. In those cases in which the contact of ether vapor proves irritative to the bronchial passages a more or less profuse mucous excretion will be excited, which, mixed with the increased salivary outflow, often accumulates in the fauces in quantities sufficient to obstruct respiration. Even when anæsthesia is considerably advanced the patient often automatically relieves himself of these accumulations, and in a manner quite regardless of the safety of those around him. When relief is not obtained by coughing and spitting, the surgeon can sometimes clear the fauces by means of a linen napkin or handkerchief wrapped around the forefinger. When all means fail and the accumulations still persist, as indicated by bronchial and pharyngeal râles and obstructed respiration, the administration of the ether should be discontinued until the patient has recovered consciousness sufficiently to free the air-passages by voluntary effort, when the giving of the ether may again be resumed, a greater degree of tolerance of the vapor being usually manifested by the mucous surfaces.

Vomiting or the effort to vomit often occurs during the administration of ether. Unless the stomach contains food this reflex movement is troublesome rather than dangerous; but as the surgeon can rarely be absolutely certain that the stomach is entirely empty, it is always advisable to discontinue the anæsthetic and turn the patient into such a position that ejected substances may fall out of the mouth and not back into the fauces, whence they might possibly be drawn into the larynx. The safe accomplishment of the act of emesis is the assurance of a danger passed, and the administration of the anæsthetic may be continued with increased confidence.

As the patient passes gradually under the influence of the drug, that stage of narcosis (second stage of Brunton) arrives in which, while conscious cerebration has ceased and the sensory and nervous systems have become partially paralyzed, the motor nervous tracts still remain capable of a high degree of excitation, the result generally being that the muscular system is thrown into a state of rigidity or becomes the seat of convulsive movements tetanic in character, and, as already stated, often very violent in degree. Under these circumstances the patient must be restrained with whatever force may be necessary from inflicting violence upon himself or others. Frequently the muscles of respiration will share in the general rigidity, and all respiratory movement cease for what often appears to the anxious operator to be an interminable period, but which really rarely exceeds fifteen or twenty seconds of time. This cessation of respiration is not by any means an alarming symptom, and must not be confounded with that due to paralysis of the respiratory centres, which is one of the accidents of anæsthesia to be hereafter considered: the general muscular rigidity, the full and bounding pulse, the absence of lividity,—all indicate that the cessation of respiratory movement under consideration is less grave in character. Indeed, its duration is self-limited: the ether vapor already diffused in the blood, reinforced by that which during this period of pause passes from the lungs into the circulation, soon produces muscular relaxation—an effect which is hastened by the want of oxygen; which latter want, too, speedily impels to fresh respiratory movements.

As soon as respiration is resumed the operator should be ready with a freshly-charged inhaler to renew the administration of the anæsthetic and bring the patient, with as much expedition as is compatible with safety, to the third or anæsthetic stage of the process, in which there is universal functional depression, attended by complete loss of sensibility; which stage begins as muscular rigidity is succeeded by muscular relaxation, and is completed only when muscular relaxation is absolute.

In bringing the patient to this stage of anæsthesia the careful operator should be studiously watchful of its progressive phases: knowing the normal physiological effects of the drug, he will be able to differentiate them from those which are unusual and dangerous in character. The condition of the pulse should be carefully observed, not so much as an index of the progress of anæsthesia as of the safety of that progress: any irregularity in rhythm or sudden failure in strength should be promptly recognized and met by appropriate measures; as, too, should like aberrations in the respiratory function.

Tests for Full Anæsthesia.—Full muscular relaxation is regarded as the best general test as to the completeness of anæsthesia and the fitness of the patient for the surgical procedure. This test is best applied by lifting the arm of the patient to a moderate height and releasing it: if upon being released the arm falls perfectly flaccid and powerless, a degree of muscular relaxation is indicated which is compatible only with a narcosis so advanced as to involve in a full degree the general sensory tracts, and general sensation will, as a rule, be found abolished.

A more delicate test, and one preferred by many, is an appeal to the nerves of sensation themselves. The point usually selected for this experiment is the conjunctival surface at the ciliary border. To apply the test, place a finger below the eyebrow and gently raise and slightly evert the eyelid, lightly touching its everted edge with a finger of the other hand. Any winking or spasmodic closure of the eyelids under this palpation is evidence that the anæsthesia is not yet absolute; but if they remain immobile an almost total abolition of sensation is indicated, and the most severe surgical operation can be performed without pain.

Prolongation of the Anæsthetic State.—If the operation is a prolonged one, the administration of the anæsthetic should be continued from time to time throughout its progress, the administrator, as already enjoined, confining his attention strictly to this duty, and not allowing his mind to be diverted from a careful observance of the condition of the patient by a desire to watch the progress of the operation. In operations upon the oral cavity the inhaling apparatus must of necessity be laid aside, at least for a time, and in dentistry a renewal of the anæsthetic is rarely necessary. In oral surgery, however, operations are frequently so prolonged that fresh doses of the anæsthetic become very desirable; but owing to the profuse and often frightful hemorrhage which, in consequence of the vascularity of the parts, attends this class of operations, a renewal of the anæsthetic is attended with no inconsiderable danger, and for its safe accomplishment requires both skill and courage on the part of the operator. The best method of avoiding the danger of suffocation under such circumstances is to place the patient upon one side, or even face downward, thus allowing the tongue to fall forward and the blood and saliva to flow out of the mouth instead of into the pharynx. This expedient, together with the frequent sponging of bleeding surfaces, will enable the operator to reapply the inhaler and bring the patient again fully under the anæsthetic influence.

Treatment of Patient after Anæsthesia.—Upon the completion of the operation, especially if it has been at all severe or prolonged, the patient should be kept under careful surveillance for several hours, or, in any case, until he has fully rallied from shock or depression. The proper temperature of the room in which he is placed has already been alluded to, and its importance must here be emphasized. Many cases of fatality are doubtless attributable to the depressing effects of cold in apartments imperfectly heated: after an operation attended by a great loss of blood the depression produced by this loss, as well as that due to the anæsthetic, will be intensified by external cold, and under these combined influences the vital powers may collapse. When, as often occurs in army practice, it is not possible to secure apartments properly heated, the temperature of the patient may be maintained by means of heated applications made directly to the body: heated bricks, cloths, bottles of hot water, etc. are among the most useful, and should be freely used until the patient has fully rallied.

THE TIME REQUIRED, AND THE AMOUNT OF ETHER USED, IN PRODUCING ANÆSTHESIA.—The time required to produce the anæsthetic state by means of ether, as well as the amount of the drug usually necessary, both vary with the age, sex, and susceptibility of the patient, the purity of the drug, the temperature of the room, and the skill of the administrator.

In twenty-six cases reported by Surgeon-major J. H. Porter, assistant professor of military surgery,[1] the following results were obtained:

	Min.	Sec.
Shortest time taken to place the patient under the influence of ether . . .	3	30
Longest time " " " " . . .	24	0
Average time " " " " . . .	8	10
Average time under influence	19	6
Smallest quantity used in any one case	2 oz. 4 dr.	
Largest quantity used any one case	9 "	
Average quantity used	5 " 1 "	

Vomiting occurred in eleven cases during or after the administration of the drug.
Excitement occurred in seven cases to a marked degree during or after administration of the drug.
The ether had a specific gravity of 720.2 at 64° F., and was given on an empty stomach by means of Morgan's inhaler.

As to time and amount, these averages are fairly representative of those usually observed in anæsthesia produced by means of ether when an inhaling apparatus other than the cone and sponge is used. The latter form of inhaler is more wasteful, and by its use anæsthesia, although more safely produced, is not effected so rapidly as by more complicated forms; by its use, too, better average results as to vomiting are obtainable than those given in the report.

ILLUSTRATIVE EXPERIMENTS.—In concluding the subject of anæsthesia by the inhalation of ether the following graphic description by Anstie[2] of experiments upon the human subject, one being upon himself, is here quoted as conveying to the reader a more vivid conception of the phenomena attending ether narcosis than can be obtained from a more formal statement of the sequence of physiological effects usually to be observed:

"In the following experiments an apparatus was used which was a close imitation of that employed by Snow, and figured in his work on anæsthetics. One or two ounces of ether were placed in the interior of the evaporation-box, which was occupied by a spiral so arranged as to compel the atmospheric air to pass over a large surface of ether on its way to the mouth. The tube and facepiece were those of an ordinary Snow's inhaler; the latter was accurately adapted to the face.

"*Experiment I.*—The apparatus having been charged as above described, a man aged forty, in sound health and of muscular build, commenced inhalation for the purpose of allowing an examination of his eyelids, as he had two days previously got a 'spark' of something from the furnace of a forge into his eye, and the part was so unnaturally sensitive that he could not bear it to be handled.

"No voluntary struggling took place, and the vapor did not appear to

[1] See Erichsen's *Surgery*, pp. 61, 62. [2] *Stimulants and Narcotics*, pp. 256–259.

irritate the air-passages. Respiration, which at the commencement was 16 per minute, retained this rate during the whole of the first minute. The pulse (which at the commencement of inhalation was 74) mounted during that time to 96, and was very forcible in its beat. Sixty-five seconds from the first inspiration of ether the patient sat up and looked at me with a roguish leer for a moment or two. He then sank back, and began to babble incoherent nonsense with great fluency, and at first with perfect articulation: by the end of the second minute the pulse had risen to 104, respirations 18; eye somewhat congested, face of the natural tint, pupil apparently unaffected in size and quite sensitive to changes of light. There was now very perceptible diminution in the sensibility of the skin of the hands; there was also commencing rigidity of the muscles of the arms and forearms, and more decided stiffness of the legs. At the end of the third minute articulation had become confused; there was a copious flow of frothy saliva, which the patient made no effort to get rid of; consciousness was apparently lost; muscular rigidity was general and very strong, particularly in the muscles of the neck; face flushed and sweating; eyes very much congested, pupil contracted and insensitive. Pulse 98, respirations 28. At this moment an attempt was made to explore the injured eye, but the lids closed with spasmodic firmness at the first touch on the conjunctiva of their edges. Inhalation was continued for two minutes longer: at the end of this time muscular rigidity had disappeared, the patient was profoundly unconscious, the pupils dilated, and the conjunctiva perfectly insensitive; pulse 96, respirations 21; snoring. The eye was now explored, and the foreign body removed in less than a minute. The patient had completely regained consciousness at the end of seven minutes from the withdrawal of the ether inhaler; pulse 72, respirations 15. At this time, however, and for several minutes longer, there was still some feeling of numbness in the feet and in the calves of the legs, slight dizziness, and a slight deficiency in the co-ordination of the movements of the lower limbs in walking. On examining the inhaler three ounces of ether were found to have been used.

"*Experiment II.*—An ounce of ether having been placed in the inhaler, the facepiece was made fast to my own face by strips of adhesive plaster. My watch was placed before me in such a position that I could easily see the movements of the second-hand. With pencil in hand I made a simple mark upon paper for each fifteen seconds so long as consciousness lasted: I had no assistant in this experiment.

"With the exception of the odor of the ether being very unpleasant, my sensations were highly agreeable, and no irritation of the air-passages was occasioned, although the outer valve of the facepiece was left more than three quarters closed from the first. The first symptoms were those of simple exhilaration and warmth extending all over the body: the pulse was somewhat increased in frequency, and the heart's action became strong and perceptible to myself. For more than thirty seconds I experienced no other feelings than these. A sense of numbness and indistinct tingling then began to affect the feet, and spread upward with considerable rapidity. Almost simultaneously perspiration broke out on the forehead, and I began to be dizzy, with a feeling as if the room was spinning round. I felt a strong inclination to laugh, and I believe I did so. It was now impossible for me to see the movements of the second-hand of the watch or even the large figures; my limbs felt like lead, and almost the last thing of which I was conscious was that my pencil fell out of my hand, and that I could neither see it on the floor nor move my foot to feel for it.

"On recovering consciousness I could not at first move any of my limbs, and the room still seemed to spin round; the facepiece was still firmly attached. It was some little time before I could distinguish the figures on my watch: when I had accomplished this it appeared that thirty-five minutes had elapsed since the commencement of inhalation. I was comfortably cool, but my face was damp with copious perspiration. There was still a sensation of numbness and tingling in all my limbs, and on attempting to walk I could not manage my legs. In less than five minutes more I had perfectly recovered. It appeared that I had only made two marks upon the paper: this proved that I had become unequal to the requisite movements or oblivious of the matter before the forty-fifth second from the commencement of inhalation. All the ether in the apparatus had been used."

Dangers of Ether Narcosis.

Attention has thus far been directed chiefly to those phenomena of ether narcosis which are usual in character, and which do not to an alarming degree impair the vital powers of the subject or put life in jeopardy; but as the whole process of anæsthesia, whatever agent be used, is simply an assault upon the functional integrity of the great centres of vitality, the toxic influence being subject only to such limitations as are inherent in the nature of the drug employed or as are dependent upon the manner of its administration, it follows that there is always a possibility that the line of safety may at any moment be passed and dangerous complications manifest themselves.

One of the marked physiological effects of sulphuric ether is that in the progressive paralysis of the vital functions which it produces the respiratory centres usually become depressed far more rapidly and deeply than the circulatory, the heart frequently continuing to beat for several seconds, or even minutes, after respiration has ceased. The dangers of ether narcosis are therefore to be looked for chiefly in this direction, and while both pulse and breathing should be closely watched, any failure in the former will generally be found to have been preceded by a marked depression in, or total cessation of, the latter function. Broadly stated, ether kills by apnœa, and not by syncope. This rule, however, is not by any means invariable, as heart failure is occasionally the first indication of danger, the respiratory movements being at the time comparatively unaffected.

Insufficient Anæsthesia.—Ether under certain conditions, as has just been intimated, is quite capable of seriously weakening the force of the cardiac impulses, and even a fatal arrest of cardiac movement may result from the combined influence of the operation and the anæsthetic. This result may, of course, follow when too much of the drug has been given, but it is also a possible consequence of giving too little. Very soon after the introduction of modern anæsthesia Sir James Y. Simpson announced as a fundamental condition of safety in ether narcosis that, "whatever means or mode of etherization is adopted, the most important of the conditions required for procuring a satisfactory and successful result from its employment in surgery consists in obstinately determining to avoid the commencement of the operation itself, and never venturing to apply the knife, until the patient is under the *full* influence of the ether vapor, and *thoroughly* and *indubitably* soporized by it."[1]

The necessity for the observance of this rule arises from the fact that in incomplete anæsthesia consciousness may be abolished while the sensory system still remains capable of receiving and transmitting impressions, so that through this system pain may be felt of which the intellectual functions can take no cognizance. The shock from this unconscious suffering may be transmitted to the cardiac and vaso-motor ganglia, already in a state of partial paralysis from ether narcosis, and upon them produce an impression so profound as to result in complete arrest of movement.

This result is possible not alone from the major operations of surgery, but has frequently resulted from operations quite trivial in character and affecting only dermal structures or their appendages. Anstie was the first to point out that the relatively great fatality in such cases was due to the fact that "certain portions of the skin and subcutaneous tissues retain their sensibility with extraordinary tenacity: these are the matrix of the great toe-nail, the margin of the anus, and the whole of the skin of the organs of generation. It is impossible," he says, "to obliterate their sensibility without pushing chloroformization to a degree which greatly surpasses that required for ordinary purposes. This observation is confirmed by my experience with animals, and its importance cannot be too highly estimated; for it explains the frequency with which death has happened in the course of anæsthesia induced for the performance of operations for phimosis, evulsion of the toe-nail, hemorrhoids, etc. All kinds of fanciful reasons have been given for this fatality of chloroform in such trifling operations, but there is no doubt in my mind that this is the true one."[2]

The peculiar toxic power of chloroform is such that fatality as the result of its insufficient use in such cases of retained sensibility is far more likely to follow than from the employment of ether; still, the danger exists with both, and must not be lost sight of. Many of the deaths which have followed the use of anæsthetics in dental surgery have no doubt been due to the insufficiency of the dose; and there can be no question that those branches of the fifth nerve distributed to the teeth, especially when their sensory activity is intensified by pulp-irritation or by inflammation of the root-investments, are among the nervous tracts which retain sensibility late in the anæsthetic process; which fact, coupled with the close connection between the nucleus of the fifth and that of the inhibitory nerve of the heart, often sufficiently accounts, even when other reasons are lacking, for the mortality which has so frequently attended tooth-extraction. As early as 1867, Dr. Reeve[3] called attention to the special danger of insufficient anæsthesia in dentistry—a position which is fully sustained by Bartholow, who says:[4]

"*Incomplete anæsthesia is a condition of danger.* Numerous accidents have occurred from the use of anæsthetics for trivial operations—notably,

[1] *Anæsthesia*, pp. 158, 159. [2] *Stimulants and Narcotics*, pp. 305, 306.
[3] *American Journal of the Medical Sciences.*
[4] *Materia Medica and Therapeutics*, pp. 362, 363.

for extraction of teeth—in which but a partial degree of insensibility is induced. In such cases the heart, enfeebled by chloroform narcosis, is suddenly paralyzed by the reflex action proceeding from the peripheral injury. The district of tissue supplied by the fifth nerve is an especially dangerous region, owing doubtless to the intimate connection of the nucleus of the fifth with the nucleus of the pneumogastric. By far the largest number of fatal cases have resulted from a neglect of this rule: it is never safe to proceed in a surgical operation with anæsthetics unless complete insensibility has been produced."

Dr. Lauder Brunton in Coleman's *Dental Surgery and Pathology*[1] gives the following explanation of the nervous mechanism through which irritation of the fifth nerve during tooth-extraction operates upon the vascular system:

"The blood when it reaches the veins is useless for the nutrition of the tissues, as we see in a corpse when the whole of the blood in the body is contained in the veins, the arteries being empty: only so long as it is in the arteries can it maintain the vitality of the tissues. The blood is kept in the arteries—1, by fresh supplies being pumped out of the venous system into the arterial by the heart; 2, by the contraction of the arterioles, which prevents it from running back too quickly into the veins.

"When a tooth is drawn without chloroform the irritation is carried by the fifth nerve to the nerve-centres: it irritates the vagus roots and also the vaso-motor centre. The irritation of the vagus may depress or arrest the heart's action, so that no blood is sent into the arterial system for several seconds; but this is counterbalanced by the irritation of the vaso-motor centre, which causes contraction of the arterioles, and thus correspondingly diminishes the outflow. In a person thoroughly under chloroform *both* nerve-centres have their reflex sensibility abolished, and so the irritation has no effect upon either; but with partial anæsthesia the vaso-motor centre may be rendered insensible before the vagus centre, and consequently when the irritation is applied to the fifth nerve the vagus centre only is excited, the heart is depressed or stopped, and the inflow of blood into the arterial system is diminished or arrested, while there is no contraction of the arterioles, and therefore no corresponding diminution of the outflow. The arterial system therefore becomes more or less empty—*i. e.* it approaches more or less the condition of death, and fatal syncope may result."

In the following diagram (Fig. 4), Dr. Brunton illustrates the course of the nervous impulses, producing arrest of the heart's action, following the extraction of a tooth from a but partially-anæsthetized person.

Signs of Danger in Ether Narcosis.

Failure of Pulse.—The chief indication of impending heart paralysis will be found in failure of the pulse, it becoming weak in quality and irregular in rhythm, these symptoms being possibly followed by its total cessation. In such cases the face and lips will become bloodless and hemorrhages from wounded surfaces will cease.

[1] See *Manual of Dental Surgery and Pathology*, by Alfred Coleman, L. R. C. P., F. R. C. S., etc., thoroughly revised and adapted to the use of American students and practitioners, by Thomas C. Stellwagen, M. A., M. D., D. D. S., Professor of Physiology at the Philadelphia Dental College, pp. 337, 338.

Interference with Respiration.—So far as interference with the respiratory function is concerned—the chief source of danger when ether is administered—the symptom which most urgently demands attention is a respiration either hurried, labored, intermittent, gasping, or stertorous. As has already been stated, the mere temporary suspension of respiration, which so often occurs as the result of the fixation of the respiratory muscles during the tetanic stage of etherization, need not excite alarm

FIG. 4.

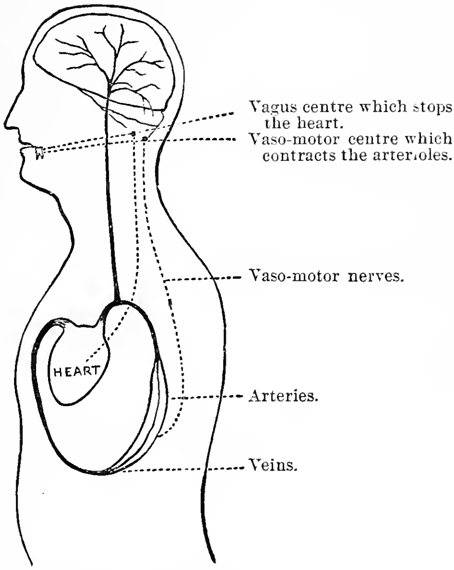


Diagram illustrating Lauder Brunton's views of the cause of arrest of the heart's action under chloroform administration.

unless attended by other abnormalities in the appearance or condition of the patient, such as great lividity of the face, irregularity or failure of the pulse, etc.; and, indeed, this statement is equally applicable to other of the aberrations in the rhythm or quality of the respiratory movement to which attention has just been called. Up to the time of complete muscular relaxation the respiration is often exceedingly irregular, at one moment hurried and at another shallow and labored; sometimes it is intermittent, the semi-conscious patient being apparently in a state of lethargy, and, for the time, quite oblivious to the necessity for breathing until aroused by the voice or touch of the operator. After complete relaxation of the voluntary muscular system has taken place, however, the respiratory movements, while slow, are usually deep and rhythmical: at this time, therefore, any abnormalities in character are to be carefully regarded. In brief, it may be stated that aberrations in the respiration are grave when they come on late in the anæsthetic process, or when in any stage they are prolonged and are attended either by excessive lividity or great pallor of the face, and by irregularity or failure of the circulation.

Gasping Respiration.—Of special significance is what has been described as gasping respiration, in which the mouth is opened widely and the air in full volume is drawn convulsively into the trachea, producing, as it passes over the vocal cords, those highly-pitched, resonant inspiratory vibrations characteristic of a gasp. This form of respiration is generally shallow or superficial in character, the air-current appearing to dilate the minute air-passages to but a limited extent, and is always indicative of a grave interference, through the respiratory centres, with the mechanism of breathing.

Stertorous or snoring respiration is a symptom demanding the closest watchfulness, and is grave just in proportion as respiration is interfered with and the muscular relaxation upon which it depends is partial or absolute. The tongue becomes partially paralyzed quite early in the anæsthetic state, as is indicated by the inability of the patient to clearly articulate words and sentences, and even in this state of incomplete paralysis it may fall back against the relaxed velum, thus shutting off the passage of air from the mouth into the larynx, except as the velum is lifted by the narrowed and intensified air-current and thrown into those rude vibrations which produce the sound of snoring. The velum, resting as it does against the dorsum of the tongue, acts as an imperfect valve to the returning air-current, and, notwithstanding that the mouth is widely open, often causes it to escape chiefly through the nasal passages. In the deeper forms of stertor this valvular function is less perfectly performed, and expiration as well as inspiration takes place through the mouth. It is, of course, evident that under the circumstances described respiration is to a greater or less extent obstructed, and thus one of the conditions vitally essential to safety in anæsthesia is impaired.

Those more complete muscular relaxations in which simple snoring deepens into a profounder stertor are of even a graver significance: the buccinators may share in the general loss of muscular power and flap to and fro in the incoming and outgoing air-currents, while the tongue may become so completely paralyzed as to fall back upon the glottis, thus not only producing an almost complete laryngeal stenosis, but indicating a degree of muscular paralysis compatible only with a profound and dangerous narcosis—a narcosis which may at any moment culminate in a complete suspension of the respiratory functions.

Laryngeal Stertor.—Lister has called attention to the fact that a snoring respiration may be purely laryngeal in character, due to "the vibration of the portions of mucous membrane surmounting the apices of the arytenoid cartilages—*i. e.* the posterior parts of the aryteno-epiglottidean folds (thick and pulpy in the dead body, but much more so when their vessels are full of blood), which are carried forward to touch the base of the epiglottis during stertorous breathing, and are placed in still closer apposition with it when the obstruction becomes complete."[1] To laryngeal stertor Lister attaches much more significance than to that dependent upon palatine vibrations.

Delusive Chest Movements.—Cases sometimes occur in which the walls of the chest rise and fall even after air has ceased to enter the lungs. This failure is not always dependent upon obstruction of the glottis, for

[1] Holmes's *System of Surgery*, vol. iii. p. 531.

in experiments upon animals it has been observed even when the anæsthetic has been administered by a canula introduced through an opening made in the trachea. Murray[1] attributes the phenomenon to a failure in the co-ordination of the inspiratory and expiratory muscles, or to an antagonism between the "action of the diaphragm" . . . . "and the action of the muscles of expiration," the result being a "respiratory stammer" precisely analogous to the inco-ordinate speech of inebriety. Whatever may be the true rationale of the phenomenon, the clinical fact is of the utmost practical importance, for unless instructed in regard to the possibility of this danger the operator, deceived by the continuance of the chest movements, would fail to notice that the lungs are no longer receiving air until warned of the fact by signs of impending asphyxia or collapse.

Irregularities of Pulse.—All the more serious interferences with respiration are always attended by aberrations in the force and frequency of the pulse. Even with ether it sometimes, although rarely, happens that as the result of organic weakness or susceptibility the circulation is primarily affected, the pulse becoming weak, irregular, intermittent, fluttering or running, or even ceasing altogether, these evidences of cardiac paralysis being, of course, followed by abnormalities in respiration. In syncope the hemorrhage from wounded surfaces ceases. In apnœa the blood assumes the venous hue due to imperfect aëration.

The methods for antagonizing these dangerous conditions now demand consideration.

Treatment of Dangerous Symptoms.

Whenever in the progress of ether narcosis dangerous symptoms are manifested the primary indication is the withdrawal of the anæsthetic, the simple readmission of full volumes of fresh air to the respiratory tract often sufficing to effect the recovery of the patient. As the air of the room in which the ether has been given is generally pretty thoroughly impregnated with the vapor of the drug, it is well to open doors or windows, as may be most convenient, for the purpose of admitting a purer air from the outside. During cold weather, however, care must be taken that the temperature of the room, and consequently of the patient, is not too much lowered by this freedom of ventilation, cold, as has already been explained, being quite capable of effecting a fatal depression of the vital powers.

This consideration must be borne in mind when the dashing of cold water into the face or upon the chest is resorted to. The object is, of course, to excite the reflexes to activity by a sudden stimulation of the superficial sentient nerves; but as these undergo a paralysis more or less complete quite early in the anæsthetic state, the plan is hardly likely to prove so effective as it would in an ordinary case of fainting or syncope; still, there are many cases on record in which apparent benefit has been derived from this practice; but the fact must not be lost sight of that a too prolonged exposure to cold water or the too frequent application of the douche is certain to do harm.

[1] *British Med. Journ.*, Sept. 19, 1885.

A far more effective method of exciting the reflex activity of the respiratory system is stimulation of the pharyngeal branches of the pneumogastric. This may be effected by passing the finger into and touching the walls of the fauces, where, and in the mucous membrane of the larynx, sensation is retained to a very late period in the anæsthetic process.

No small part of the benefit derived from drawing forward the tongue when it has fallen back into the fauces is unquestionably due to the reflex stimulation of the respiratory centres which its forcible extension produces.

It has thus far been assumed that the directions already given as to the preparation of the patient for, and position during, the inhalation of the anæsthetic have been fully followed. If, however, the clothing has not been so fully loosened as to give the utmost freedom of movement to the walls of the chest and abdomen, this should at once be done; and if the patient has not been kept in the recumbent position, he should without a moment's delay be so placed, thus favoring the flow of blood to the brain by the force of gravity, and to that extent diminishing the force of the cardiac contraction required to effect its impulsion thither. Indeed, where the evidences of cardiac failure are very marked, and great pallor of the face and lips indicates a state of cerebral anæmia, it is desirable that the head should not only be as low as, but lower than, the rest of the body; in extreme cases even the inversion of the body has been recommended and successfully practised by Nélaton and others. This, however, is a procedure more likely to be demanded when chloroform has been employed as an anæsthetic, and it will be further commented upon in connection with the use of that drug.

Howard's Method.—Allusion has already been made to the pulling forward of the tongue when it has fallen back into the pharynx; and this act of simple traction upon the organ has generally been regarded as amply sufficient to relieve the mechanical obstruction to respiration due to its abnormal position. Dr. Benjamin Howard was the first to call attention to the fact that in the supine position ordinarily assumed in anæsthesia the forcible drawing forward of the tongue in cases of respiratory obstruction has very little if any effect in lifting the epiglottis and thus permitting free access of air to the larynx. Dr. Howard recommends that the patient be placed upon his back, with a bundle of clothing or some other firm substance under the shoulders for the purpose of elevating the thorax, the head and neck to be placed in extreme extension backward; thus the patient will be lying with the under part of his chin rather than his face presenting to the ceiling of the room; in other words, the head of the patient is in very much the same position as if his whole body was inverted. It is evident that when a man is thus placed, head downward, a paralyzed tongue by simple gravitation will fall against the roof of the mouth, whereas in the supine position, face upward, gravitation naturally carries it against the posterior wall of the pharynx.

Dr. Howard claims that the extreme extension backward of the head and neck which he recommends effects such extensions and adjustments of the muscular apparatus of the throat, larynx, and fauces as secure, if the nares be permeable, an unobstructed "post-oral air-way," the mechanism, as described by Dr. Howard, being as follows:[1]

"The position consists in elevation of the thorax and complete extension backward of the head and neck. By this means the line of gravitation of the tongue is shifted from the back of the pharynx to the hard palate at or about its junction with the soft palate. The entire posterior wall of the pharynx is shifted backward, its anterior wall is shifted forward; thus its antero-posterior diameter, as much as is possible, is throughout increased, while by the shifting upward and backward of the nares their entrance is brought more directly over, and in a line with, the course of the pharynx.

"The larynx being pulled downward and forward by the sterno-hyoidei muscles, and fixed there, the extension motion upward and backward of the lower jaw puts upon the stretch the genio-hyoidei, mylo-hyoidei, and anterior bellies of the digastric muscles, causing the hyoid bone and—by means of the hyo-epiglottic ligament—the epiglottis to share together the motion of the jaw. Thus the epiglottis is instantly made vertical, the thyroid insertion of the palato-pharyngei muscles being brought downward and forward by the sterno-thyroidei and fixed; the palato-pharyngei muscles are put upon the stretch in their whole length by the movement upward and backward of the head in extension, and thus the posterior pillars of the fauces, the arches of the palate, and velum palati, into which latter membrane they are inserted, are all pulled downward and forward; they are thus made tense, and kept so. The velum thus stretched some distance in front of the back of the pharynx, a post-oral air-way is secured, from which the tongue is doubly excluded."

These anatomical points have been demonstrated by Dr. Howard upon the cadaver, and the advantages of the position he recommends are now generally conceded.

Drawing Forward the Tongue.—Dr. Howard regards the drawing forward of the tongue, in connection with his position of extreme extension backward of the head and neck, as "highly advantageous, though not necessary," but recommends that when it is attempted the jaw should be lowered as little as possible.

In attempting traction upon the tongue it may sometimes be successfully grasped by the fingers protected from contact with its slippery surface by a dry towel or napkin, or a pair of large bullet forceps similarly protected may be used. A tenaculum has been recommended, but this is too slight an instrument to be used in making the necessary traction. Kappeler[2] recommends in extreme cases piercing the tongue through its entire thickness with a thread sufficiently strong to bear the strain necessary to effectively draw the organ out of its malposition. This author has demonstrated on the cadaver (as did Howard) that drawing forward the tongue "has only the effect of opening the pharynx, while the epiglottis remains unmoved or is hardly observably

[1] "An Anatomical Remedy against Respiratory Obstruction from the Tongue, Epiglottis, and Velum Palati in Threatened Apnœa from Anæsthesia and Other Causes," by Benj. Howard, A. M., M. D., M. R. C. S., Eng: *Proceedings Med. and Chirurg. Soc.*, May 14, 1878, pp. 331–333.

[2] *Anæsthetica*, pp. 126, 127.

lifted, unless the traction is so strong that both the under jaw and the hyoid bone are drawn forward with the tongue."

Drawing Forward the Under Jaw.—In this connection Kappeler recommends a method of drawing forward the under jaw, to be accomplished by placing the thumbs upon the cheeks of the patient close to the nose, the bent fingers behind the angle of the jaw upon either side, and making the traction required. He has shown upon the cadaver that "through the drawing forward of the lower jaw the tongue and hyoid bone are also moved forward; the epiglottis, following through tension upon the hyo-epiglottic ligament, will be placed upright, so that when one can" (in a prepared cadaver) "look from above into the throat, the rima glottidis will be seen coming fully into view."

When any or all of these efforts to relieve mechanical obstruction or to excite the respiratory reflexes fail to accomplish their purpose, recourse must be had to some one of the methods of artificial respiration.

Artificial Respiration.

Insufflation.—One of the oldest methods of inducing artificially the inflow and outflow of a current of air through the respiratory tract is the inflation of the lungs of the subject directly from those of the operator by the mouth-to-mouth process. This often succeeds with newly-born infants, but certain mechanical obstacles render it difficult of accomplishment with adults, one of the chief of these being that of securing a coadaptation of the labial orifices sufficiently close to establish a continuous and unbroken air-passage. This difficulty can be overcome by interposing a tube between the mouths of the operator and the subject respectively, the lips of the latter being closed around the tube by the fingers either of the operator or of an assistant. Or the delivery end of the tube may be placed in one nostril of the patient, the other nostril and the mouth being firmly compressed to prevent the escape of air. For this reason compression of both nostrils must be practised where the mouth is used as the avenue for inflation; and in order to prevent the air from passing into the œsophagus and stomach, instead of the trachea and lungs, the larynx should be firmly pressed backward for the purpose of compressing the œsophagus between the laryngeal walls and the spinal column. The objection urged against these methods of direct insufflation, that air coming directly from the lungs of one person contains too little oxygen and too much carbon dioxide to satisfy the respiratory needs of another, is only measurably true: respired air is contaminated, but is by no means absolutely useless for breathing purposes, and, in point of fact, must be breathed and rebreathed several times before it becomes entirely unfitted to sustain life. The operator may very much improve the quality of the air which he blows into the lungs of the patient by filling and emptying his own lungs several times in rapid succession previous to each act of insufflation. The whole process, however, is, with adult patients at least, laborious and disagreeable in its details and difficult of successful accomplishment: its great merit is that the mouth-to-mouth process can be resorted to without the delay incident to the use of artificial inflating apparatus, while by the use of the latter a purer air is obtained and fatigue upon the part of the operator is avoided.

The ordinary fire-bellows is the most familiar and efficient, as well as the simplest in its construction, of these forms of apparatus. Of more modern construction are insufflation-tubes attached to bulbs of elastic rubber, the bulbs being furnished with valves so arranged as to admit air at their free ends and under suitable compression allow its egress only at the other or tube ends. By placing the nozzle of such a tube or of the ordinary bellows in one nostril or in the mouth of the patient a speedy inflation of the lungs may be effected, it being of course understood that the same precautions are to be observed as in direct insufflation.

Whichever of these methods may be adopted, care must be observed not to distend the lungs of the patient too forcibly, owing to the possibility that rupture of the air-vesicles may thereby be caused. The object of the operator should be simply to gently distend the lungs to about the same degree, and with about the same frequency, as in normal respiration. The elasticity of the lung-tissue and of the thoracic walls is usually sufficient to produce a satisfactory expiratory result, although this may be assisted by gentle compression of the walls of the chest. When the thorax becomes apparently expanded, and so remains without subsidence, it may be taken as an indication that through some failure in manipulation the air-current has followed the line of least resistance, and passed into the œsophagus, instead of the larynx ; indeed, any other result will be impossible if access to the latter is closed by pressure of the tongue upon the epiglottis. In such cases placing the patient in Howard's position would seem to be the only means of rendering possible any method of insufflation through the oral or nasal cavity : certainly, the expedient suggested by some writers of passing the insufflation-tube through the rima glottidis into the larynx will be found difficult, if not impossible, of accomplishment, except perhaps by expert laryngologists.

Tracheotomy.—A far more practicable and effective procedure, and one which in extreme cases should always be adopted, is the performance of tracheotomy. This is especially effective in spasm of the glottis or in pharyngeal or laryngeal obstruction proceeding from whatever cause, and even in cases of true respiratory paralysis it affords, other methods failing, the most effective means of emptying the lungs of ether vapor and of re-establishing by insufflation the normal respiratory current. It is quite certain that lives have been saved by a prompt recourse to this method, and that many more might have been had it been resorted to.[1]

Report on Suspended Animation.

In concluding the subject of insufflation the views regarding "the position of the tongue and its influence in impeding the entrance of air," expressed by the committee appointed by the Royal and Medico-

[1] For a description of the operation of tracheotomy the reader is referred to the article on "Oral Surgery," Vol. III.

Chirurgical Society to investigate the subject of suspended animation, may here be quoted. The views as given are the result of careful experimentation upon the cadaver, and, as will be seen, fully sustain—or, rather, anticipate—Howard's position upon the point, his method having been published many years after the report of the committee was given to the world. The committee say:[1]

"It was found that in the dead body this organ" (the tongue) "is apt to offer great obstruction to inspiration by falling back into the pharynx and closing the laryngeal aperture. No air could be forced through the mouth in a body lying on the back so long as the tongue remained undisturbed, but when it was drawn forward and held out of the mouth by a ligature or by the pressure of the teeth upon it, air could be injected by the œsophagus and larynx, so as to distend both the abdominal and thoracic cavities.

"*When the head of the subject was allowed to hang back over the edge of the table, air seemed to pass into the chest more readily than when the back of the head rested against the table.*

"It was found that the whole quantity of air introduced by inflation could be compelled to enter the respiratory cavity by pressing back the larynx against the spinal column. By this expedient the passage of air down the œsophagus was at once interrupted, while its transit down the trachea continued as before; so that it affords a ready means of preventing the passage of air into the stomach during artificial respiration."

Manipulative and Postural Methods of Artificial Respiration.

These methods, although differing in detail, have for their purpose the placing of the patient in positions best fitted to favor normal respiratory movements and of reproducing artificially those movements by alternate manual compression and relaxation of the walls of the thorax.

Dr. Marshall Hall's Method.—This has been called the "ready method" or "the method of prone and postural respiration." It consists in placing the patient in the prone position, making gentle pressure upon the back, turning the patient upon his side and a little beyond (or nearly supine), replacing him briskly upon his face, making gentle pressure upon the back, and turning upon the side as before; these movements being repeated about fifteen times in the minute until natural respiration is resumed.

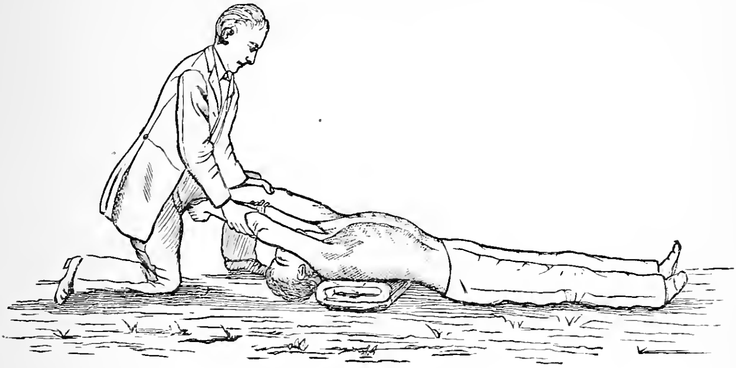
As the patient in the execution of these movements is placed face downward, the weight of his body, aided by pressure upon the back, compresses the walls of the thorax, diminishes its calibre, and forces out a portion of the residual air contained in the lungs. As the patient is turned upon his side this mechanism is reversed; the chest-walls, being relieved of pressure, immediately, by virtue of their elasticity, expand; a corresponding increase in chest capacity occurs, the inflow of air into the lungs being favored by the partial vacuum thus created.

Dr. Silvester's Method.—The essential features of this method, as at present practised, are as follows: Place the patient supine upon a flat

[1] Report read July 1, 1862: see *Med.-Chirurgical Transactions*, vol. xlv.

surface, the chest being elevated by a cushion placed beneath the shoulders, the head hanging backward in Howard's position. Standing behind the head of the patient, grasp his flexed arms near the elbow and draw the extended arms upward and forward upon either side of the patient's head (Fig. 5), for the purpose of putting upon tension the

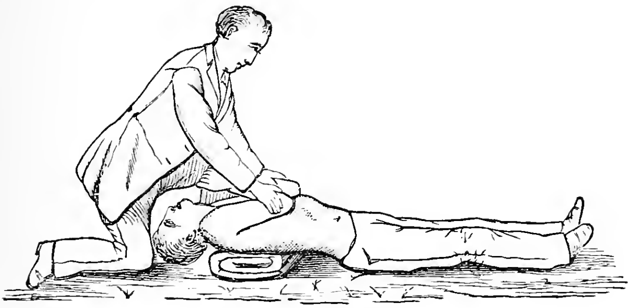
FIG. 5.



Inspiration (Silvester's method).

pectoral muscles, and thereby elevating the ribs and increasing the chest capacity: to effectually accomplish this pull strongly upon the arms for the space of about two seconds. Then flex the forearms upon the arms and press them firmly against the sides of the chest to expel the air (Fig. 6). Repeat these movements about fifteen times in the minute.

FIG. 6.



Expiration (Silvester's method).

Dr. Howard's Direct Method of Artificial Respiration.—This is the most recently introduced, and perhaps, in its essential features, the most approved, of all the methods now in use. As published in the *London Lancet*,[1] it was prefaced by directions for securing the ejection and drainage of fluids from the stomach and lungs of drowned persons; which directions, although not strictly germane to the subject of anæsthesia, may, as a matter of general interest, be here given; they are as follows:

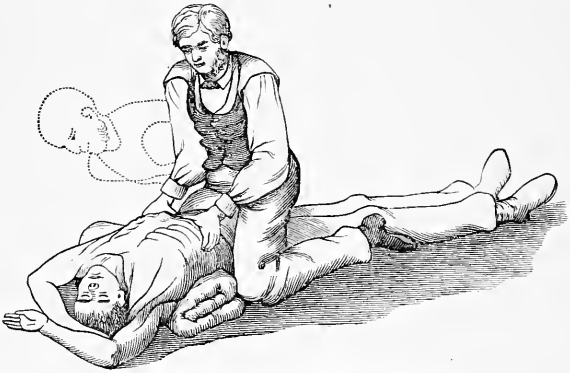
[1] August, 1878, pp. 362–368.

"*Position of Patient.*—Face downward, a hard roll of clothing beneath the epigastrium, making that the highest point, the mouth the lowest. Forehead resting upon forearm or wrist, keeping mouth from the ground.

"*Position and Action of Operator.*—Place the left hand well spread upon base of thorax to left of spine, the right hand upon the spine a little below the left and over lower part of stomach. Throw upon them with a forward motion all the weight and force the age and sex of patient will justify, ending this pressure of two or three seconds with a sharp push, which helps to jerk you back to the upright position. Repeat this two or three times according to period of submersion and other indications.

"*To Perform Artificial Respiration.*—*Position of Patient* (Fig. 7).—Face

FIG. 7.



Artificial Respiration (Howard's method).

upward, the hard roll of clothing beneath thorax, with shoulders slightly declining over it. Head and neck bent back to the utmost. Hands on top of head. (One twist of handkerchief around the crossed wrists will keep them there.) Rip or strip clothing from waist and neck.

"*Position of Operator.*—Kneel astride patient's hips; place your hands upon his chest, so that the ball of each thumb and little finger rests upon the inner margin of the free border of the costal cartilages, the tip of each thumb near or upon the xiphoid cartilage, the fingers fitting into the corresponding intercostal spaces. Fix your elbows firmly, making them one with your sides and hips: then—

"*Action of Operator.*—Pressing upward and inward toward the diaphragm, use your knees as a pivot and throw your weight slowly forward two or three seconds until your face almost touches that of the patient, ending with a sharp push, which helps to jerk you back to your erect kneeling position. Rest three seconds; then repeat this bellows-blowing movement as before, continuing it at the rate of seven to ten times a minute, taking the utmost care on the occurrence of a natural gasp gently to aid and deepen it into a longer breath until respiration becomes natural. When practicable, have the tongue held firmly out of one corner of the mouth with thumb and finger armed with dry cotton rag."

Howard's views with regard to the influence upon the position of the tongue which is exerted by extreme backward extension of the head and neck have already been given in connection with the subject of insufflation. His opinion as to the influence upon thoracic expansion produced by the position directed for the patient in his method is given as follows:

"1st. By straightening the dorsal curvature of the spinal column. The weight of the trunk resting at this point with its greatest thoracic curvature upon the hard roll of clothing, the curve is diminished, the spinal column is proportionately straightened and lengthened, many of the ribs are moved upward, the interspace between them is increased, the sternum is carried forward, and the general thoracic circumference is thus enlarged.

"2d. By extension of the head and neck. This brings into play the scaleni, sterno-cleido-mastoidei, and all the muscles from the head and neck attached to the upper part of the thorax.

"3d. By extension of the arms. This being directly upward and backward, instead of upward and forward, as in Silvester's position, not only are the same muscles his position uses made more tense, but other muscles, the latissimus dorsi, are also brought into play, and thus the superior costæ, the inferior costæ, and as nearly as possible all the parts of the entire thorax, are submitted to the traction of the muscles presiding respectively over the expansion of those parts."

The Medico-Chirurgical committee on suspended animation, already quoted, carefully tested upon the cadaver the methods of Marshall Hall and Silvester. The following are the results:

"*The Marshall Hall Method.*—As regards that part of the method which consists in turning the body 'very gently on the side and a little beyond, and then briskly on the face,' it was found that the volume of air exchanged was variable in the same subject, but always inconsiderable. It usually happened that a quantity of air varying from one to eight cubic inches—never more, generally much less than eight—was inspired when the body was turned from the supine position to one side. When the body was placed on the abdomen, with the head resting on the forearm, a somewhat larger quantity was expelled, never exceeding ten cubic inches. On restoring the body to the lateral posture the amount of air inspired was usually less than that which had been expelled by pronation. . . . .

"The volume of air expelled when the body was placed on the face was much increased if pressure were at the same time made on the spine. . . . . As regards the whole amount of air introduced, it varied much according as the subject was favorable or the contrary, sometimes not exceeding a few cubic inches, but never exceeding fifteen cubic inches.

"*Dr. Silvester's Method.*—As regards the method above described as that of Dr. Silvester, it was found that on extending the arms upward a volume of air was inspired into the chest which varied, in different subjects, from nine to forty-four cubic inches. . . . . On restoring the arms to the side the quantity expelled was generally nearly equal to that previously inspired, occasionally less.

"Dr. Silvester recommends that on bringing down the patient's arms they should be gently and firmly pressed against the sides of the chest, so as to diminish the cavity of the thorax. It was found that this pressure could be exercised with greater facility and equal effect by placing the hands" (of the operator) "on the lower third of the sternum, as already above described" (making pressure there). "By alternating the movements of the arms with pressure of this kind a regular exchange of air was produced, the quantity of which in several instances exceeded thirty cubic inches, and in one instance amounted to fifty cubic inches.

"As has already been pointed out by Dr. Silvester, the condition of the thorax after cessation of breathing being that of expiration, it is desirable that the first step in the restoration of breathing should be a movement of expansion; in this respect the method he has proposed enjoys a marked superiority over that of Dr. Marshall Hall, which has for its object to force air from a chest which has already discharged its natural quantity. It also appears to be an important advantage in this method that in each movement of expansion both sides of the chest are left free from compression, and therefore free to move, while the postural method of Dr. Marshall Hall leaves only one side free to expand."

This indorsement of the Silvester method, as modified, was, as previously stated, made before Dr. Howard's process had been given to the public. Had the committee then had opportunity to pass upon it, they could hardly have failed to have anticipated the verdict of later observers, that this, while embracing all the essential excellences of the method of Dr. Silvester, is in point of convenience and efficiency a decided improvement upon it, and is beyond question the best of all known modes of producing artificial respiration in cases of suspended animation.

Faradization.—One of the advantages of Howard's "direct method" is that it does not preclude the simultaneous employment of additional agencies for restoring the respiratory function. One of the best of these is excitation of the movement of the diaphragm through faradization of the phrenic nerves. This form of electrical stimulation may be applied by placing the positive and negative electrodes respectively over the course of the right and left phrenic nerve in the neck, or one electrode may be applied to either nerve in the neck, and the other to the intercostal space nearest the attachments of the diaphragm upon the opposite side of the body. The latter course probably gives the best results, and when it is adopted the left side of the neck and the right side of the body should be selected, owing to the danger that in passing a current through the left side of the thorax an arrest of the movements of the heart may be caused by a possible diversion of the course of the electric fluid to that organ, this in anæsthetized animals, especially when chloroform has been employed, having frequently proved fatal.

The phrenic nerve in the neck is somewhat deeply seated, and the production of a direct impression upon it is rendered difficult by its dense covering of muscles and fascia. This difficulty can be best overcome at the point where the nerve crosses the scalenus anticus muscle; here it can be quite closely approached by pushing inward, toward the median line, the outer border of the sterno-cleido-mastoid muscle, beneath which it lies: by holding the muscle thus retracted, and at the same time pushing the electrode firmly in toward the nerve, a current through it can usually be established as soon as the other electrode is brought near the terminal filaments of the nerve distributed to the under surface of the diaphragm upon the opposite side of the body. Here the sixth or seventh intercostal space should be selected. Both electrodes should be small, and both tipped with sponges wet in water, hot when practicable, in order that the temperature of the body may be maintained. As soon as the circuit is established the diaphragm will be thrown into strong contraction. The completion of the circuit should be so timed that this contraction will take place simultaneously with those movements of artificial respiration designed to promote inspiration; that is, when the walls of the chest are raised: by this means the calibre of the thorax will at the same moment be increased in all directions, the diaphragm being depressed and the ribs elevated concurrently as in normal respiration. If this rule is followed, the circuit will be broken when the ribs are compressed by the operator, and renewed when they are released from pressure. If Dr. Howard's method and directions are followed, this will occur at the rate of from seven to ten times in the minute.

Care should be taken to give to the current only a moderate degree of intensity. The normal movement of the diaphragm is gentle and rhythmical, and these qualities it is desirable, as far as is possible, to reproduce in the process of artificial stimulation of its functions. A fiercely energetic current will not only result in the fixation of the diaphragm in a tetanic spasm, entirely unlike its natural contractile movement, but will speedily exhaust both its nervous and muscular irritability, and so render all further movement impossible.

Electro-puncture.—This method for stimulation of the diaphragm has been recommended by various writers upon the subject, the course usually proposed being that of puncturing the skin over the lower intercostal spaces of either side with insulated electric needles, and passing the current through them instead of through the ordinary electrodes. Even the penetration of the diaphragm itself has been advised, and Dr. Alfred C. Garrett, in a work on medical electricity, gives the details of a case of resuscitation after prolonged immersion, in which he states that "long gold electro-puncture needles, well insulated except at the points, four in number and four inches in length each, were carefully inserted in quick succession some two or three inches apart along the front sides of the chest, two in the lower part of each pectoral, plunging them inward and downward between the fifth and sixth ribs their whole length, thus transfixing the pectoral, intercostal, and diaphragm muscles, embracing the external nerves, and also the solar plexus and the phrenic-nerve branches."

It need hardly be stated that such hazardous and extreme measures are not to be recommended for general adoption, and it may indeed be well doubted whether even the less formidable modes of electro-puncture are practically as efficient as the ordinary electrical stimulation through the unbroken cutaneous surface. That such stimulation is a highly valuable adjunct in the treatment of apnœa is unquestionable: it, however, should not be depended upon to the exclusion of other measures, and, above all, time should not be lost in waiting for the arrival or preparation of an electrical apparatus. Let it be used, if necessary, when ready, but until then there should be no cessation of effort to restore the patient by other agencies.

General Stimulation.—Attention has thus far been directed to methods for the stimulation of special functions; but in the mean time sight must not be lost of the necessity for the careful maintenance of the general vitality. By far the most important and reliable agent in the furtherance of this therapeutic indication is heat.

Heat.—This must, in any prolonged case of suspension of animation, be persistently applied by such means as are most immediately available. Heated bricks or stones, bottles of hot water, the covers of a stove moderately hot, will answer if guarded from direct contact with the skin by a wrappage of cloths. With all such applications great care should be observed that they be not applied to the body of the patient at too high a temperature, as serious, and even fatal, burns may thus be occasioned. Relays of heated woollen cloths when they can be obtained answer even a better purpose if properly applied. The heat may be dry or the cloths may be dipped in hot water, the excess of moisture being wrung out before they are placed in contact with the body of the patient. As all such applications cool rapidly, they must be as frequently renewed. In all modes of stimulation by the application of heat to the cutaneous surface special attention must be directed to the extremities. When dry heated woollen cloths are used, the additional stimulus of friction may be imparted through their agency.

Friction.—This is a most valuable adjunct, and may be used to great advantage even without the application of artificial heat. Cloths and brushes may be employed, but a vigorous hand is more efficient than either. The friction should be brisk, but not so violent or so long continued in any one place as to produce abrasion of the skin. In executing the frictional movements the operator should endeavor to aid in the propulsion of the venous circulation from the periphery toward the heart, as the increased inflow of blood which may thus be secured will have a most important influence in stimulating that organ to renewed activity. By elevating the legs and arms gravity will favor the movement which the friction expedites.

Enemata.—As the margin of the anus and the rectum are among the last of the organs of the body to part with sensation in ether narcosis, stimulant injections may be introduced with a reasonable degree of probability that they will be efficacious in arousing dormant vitality by an excitatory impression upon the still sensitive surfaces with which they are brought in contact. *Enema terebinthinæ* (*U. S. P.*) (oil of turpentine, one fluidounce; mucilage of starch, fifteen fluidounces) may be used, or in the place of mucilage water may in an emergency be substituted; while instead of turpentine, water of ammonia may be employed in about the same proportions. In all cases the injection should be hot, so that if no other effect is produced temperature at least may be maintained. The enema should not be made too large, a gill being about all the rectum will hold without speedy expulsion.

Specific Stimulation.—Although the act of deglutition is often automatically performed even in advanced narcosis, still the introduction of stimulants into the stomach is a hazardous procedure, for with the muscles of deglutition at least partially paralyzed the patient cannot be trusted to swallow a dose placed in the mouth, as the stimulant would be quite as likely to run into the larynx as into the stomach, while, even if it reached that organ in safety, it could hardly enter the general circulation with sufficient celerity to be of any avail in the emergency under consideration. Hypodermic medication may be resorted to, but so far as whiskey and brandy are concerned, it may well be doubted whether alcoholism is not too closely allied to etherism to render the former agent a proper antidote for narcosis by the latter: they are alike paralyzers of the respiration. The intravenous injection of ammonia has been recommended, but no signal success has attended its use, and the same may be said of the employment of such tetanizing agents as strychnia, picrotoxin, etc. In case of heart failure digitalis has been administered, but it is much too slow in its action to afford any immediate relief: atropia, hypodermically, is a much more prompt and efficient agent.

Peripheral Stimulation.—The application of ammonia vapor to the nostrils is a somewhat futile measure, as but little effect can be produced upon surfaces so fully narcotized. This remark, too, holds good with reference to the application of sinapisms, etc. to the general cutaneous surfaces. The irritant influence of such agents is due entirely to an impression made upon the superficial sentient nerves, and so long as they remain without functional power rubefacients, or even epispastics, are inoperative. This has been observed in the collapse of cholera, and is equally true of the depression of vital power and suspension of functional activity due to ether narcosis.

SECONDARY EFFECTS OF ETHERIZATION.—Headache, nausea, and vomiting, cough caused by bronchial irritation or pulmonary congestion, and in young and nervous females hysteria, are among the secondary effects which most frequently follow the inhalation of ether. In the vast majority of cases these effects will disappear in a short time without any interference on the part of the surgeon, but sometimes the sequelæ are so persistent and violent in character as to demand the adoption of active remedial measures.

Headache.—For the persistent headache following ether, as it is almost invariably associated with cerebral congestion, no local measure will be found more uniformly successful than the application of cloths wet with ice-water or of bladders filled with pounded ice to the general surface of the head, and especially the lower part of the occipital region. The cerebral depletion thus induced will be much promoted by hot applications to the feet, placing them in a vessel filled with water as hot as can be borne being, as a rule, the best and most convenient of these. When merely local measures fail, the use of bromide of potassium or of opiates may be resorted to. This latter treatment is best effected by hypodermic medication, one-sixth of a grain of the acetate of morphia being given at a dose and repeated according to indications. As cerebral congestion may be succeeded by acute inflammation, or, especially in aged persons, may terminate in paralysis or apoplexy, the use of active remedial measures should not be too long delayed.

Nausea after anæsthesia is so generally associated with headache, and even when this symptom is absent is so uniformly simply a sympathetic manifestation of cerebral disturbance, that measures for the relief of the latter condition will usually overcome the gastric irritability. Persistent nausea and vomiting, even when unaccompanied by headache, are often more effectually subdued by the hypodermic use of morphia than by any other treatment. Milder attacks, however, may generally be overcome by the use of local sedatives. Small pieces of ice swallowed entire, or cold carbonic-acid water, or solution of citrate of ammonia given cold, have each proved efficacious. Benefit has sometimes been derived from the use of diluted hydrocyanic acid given in water in doses of a single drop; and the writer has had good results from the administration of single-drop doses of pure creasote made up into a pill with breadcrumb: both the hydrocyanic acid and the creasote appear to exert a local sedative or anæsthetic influence, and thus allay gastric irritability. When nausea and vomiting are violent and prolonged, persisting in spite of all remedial measures, the gravity of the situation must be recognized: such persistence not only saps the strength and vitality of the patient, but indicates serious disturbances in important nervous centres.

Cough.—The cough which is sometimes a troublesome sequela of etherization may be due to simple bronchial or laryngeal irritation, caused by contact with ether vapor; in which case it will, as a rule, disappear in a few hours without any special medication. This is the usual result, except with aged persons afflicted with emphysema or with chronic bronchial irritation or congestion, especially when the latter is due to those forms of valvular lesion which result in an undue accumulation of blood upon the venous side of the pulmonary circulation. Etherization in such cases may so intensify the congestion as to cause an almost complete occlusion of the air-vesicles, the patient slowly perishing from apnœa. In such cases of heart complication digitalis is always indicated: by the control which it exercises over the rate and duration of the diastolic and systolic movements of the heart less blood is sent to the venous side and more to the arterial side of the pulmonary as well as systemic circulation, thus relieving the stasis of blood in the pulmonary tissue. As adjuncts to this treatment stimulant expectorants, such as the carbonate or muriate of ammonium, may be administered, the strength of the patient being at the same time sustained by a diet of beef-tea and wine-whey. As a local application nothing is more effective than relays of hot-mush poultices, covering as much of the surface of the chest as possible.

Pulmonary Inflammation.—When the pulmonary congestion assumes the acute type and becomes a true pneumonia, such measures must be taken to control the violence of the inflammatory action as the conditions of the case indicate, quinine or opium, or such motor depressants as aconite and veratrum viride, being now the remedies usually resorted to.

Hysterical symptoms sometimes last for several days, but, as a rule, they speedily yield to valerian or other remedies of the "antispasmodic" group. Bromide of potassium also has been found efficacious, and frequently most prompt and satisfactory results have been obtained from the hypodermic injection of the acetate of morphia.

Etherization by the Rectum.

The rapid absorption of gases from the intestinal tract has suggested the practicability of producing systemic anæsthesia by the introduction of ether vapor into the rectum. This method, according to Treves,[1] was first suggested in 1847 by Nikolaus Pirogoff in his work entitled *Rapport médicale d'un Voyage au Caucase*, published in St. Petersburg in 1849; but it was not until quite a recent period (1884) that the plan excited any particular attention. On March 21st of that year M. Daniel Mollière, surgeon of the Hôtel-Dieu at Lyons, at the suggestion of Dr. Axel Yverson of Copenhagen, operated on a young girl twenty years of age for a small tumor in the parotid region, the ether vapor being introduced into the rectum by means of a Richardson's atomizer. In this case complete anæsthesia was not produced until a small amount of the vapor had been administered by the respiratory tract.

M. Mollière's second patient was a woman forty years of age, operated on for a polypus in the antrum. In this case the bottle containing the ether was placed in hot water (50° C.) to vaporize it more rapidly, and then passed into the rectum through a rubber tube "the diameter of a finger." In this case, too, the inhalation of a small amount of ether was necessary. There was no nausea.

The method was tested in several other cases with results so much to the satisfaction of M. Mollière that he recommended it as a plan likely to be of great service in surgery, the advantages claimed being limitation of the period of excitation; reduction and more exact measurement of dosage; absence of respiratory irritation; and the fact that in operations upon the face or in the oral cavity the ordinary inhaling apparatus can be dispensed with.[2]

Since the above experiments were reported by M. Mollière the rectal method has been employed on quite a large number of cases, the apparatus generally used consisting of a wide-mouthed graduated bottle, the cork of which is perforated for the admission of two glass tubes, one of which is provided with a funnel for the introduction of the ether and a stopcock to prevent its escape. To the free end of the other glass tube is attached a piece of rubber tubing about two feet in length, the rectal end of this tubing being armed with the vaginal nozzle of a Davidson's syringe. In the bottle, which should have a capacity of about six ounces, two ounces of ether are placed, and the bottle immersed in a vessel containing water at a temperature of from 110° to 140° F. The ether at once boils, and, the rectal tube being introduced, the ether vapor passes into the intestine. As a considerable time, from fifteen minutes to half an hour, is required to produce full anæsthetic effects, a uniform temperature should be carefully maintained by the gradual introduction of additional quantities of hot water: either the cooling or the overheating of the ether is to be avoided, as the first retards and the second unduly and dangerously hastens the anæsthetic process.

That this method is not without its special dangers is unquestionable. M. A. Poncet,[3] after several experiments, warns the profession against it as having produced in some instances dilatation of the pupil and arrest of cardiac and respiratory movements. In one instance he states that the anæsthetic sleep was prolonged for two hours and a half after the operation, and for a period of twenty minutes he despaired of saving

[1] *The Year-Book of Treatment*, 1884.
[2] See *Lyon Médicale*, March, 1884.
[3] *Ibid.*, June, 1884.

the life of his patient. In this country one death has occurred, a child eight months old.

A very marked disadvantage of the process is the rapid distension of the colon which is sometimes produced, this not only causing considerable pain, but interfering to a dangerous extent with respiratory movements. When dangerous symptoms arise, it is difficult if not impossible to expel the ether vapor from the intestinal tract, its continued absorption from that surface increasing, of course, the hazard of the situation.

In a large percentage of cases distinctly irritant effects are produced by the local contact of the ether vapor with the mucous lining of the intestine. In nearly every instance diarrhœa has followed the employment of the method, and frequently the stools have been bloody. In one case "the patient's bowels were opened ten times during the night following the operation" (Treves). In a rabbit which died under rectal etherization the entire length of the intestine was found hyperæmic, and the large intestine greatly distended (Poncet).

It will thus be seen that etherization by the rectum is subject to serious disadvantages, and until these can be overcome it is a plan hardly to be recommended for general adoption, even in oral surgery, where, for convenience, such a method would be so desirable.

Chloroform.

Chemistry.—Chloroform was discovered by Soubeiran, the French chemist, in the year 1831. In the same year Liebig of Germany and Guthrie of Sackett's Harbor, N. Y., made independent discoveries of the same substance. The newly-discovered compound was called *ether bichlorique* by Soubeiran; Liebig regarded it as a trichloride of carbon, while Guthrie described it as a spirituous solution of chloric ether; but in 1835, Dumas discovered its true chemical constitution, and gave it the name under which it is now known.

There are several methods by which chloroform may be obtained: the process usually followed is the distillation of ethyl alcohol with chlorinated lime. Methyl instead of ethyl alcohol may be used, but the chloroform produced is unfit for anæsthetic purposes.

The exact details of the chemical changes resulting from this distillation have not been definitely determined. Neglecting the possible primary or sub-reactions involved in the process, such as the preliminary formation of an aldehyd (C_2H_4O), it may be stated in general terms that the principal change consists in the displacement of five atoms of hydrogen from the alcohol molecule (C_2H_6O) by chlorine, derived from the chlorinated lime, five chlorine atoms uniting with the displaced hydrogen to form five molecules of hydrochloric acid (5HCl), and three chlorine atoms uniting with the remaining portion of the alcohol molecule to form chloral (C_2HCl_3O); this molecule being itself immediately decomposed by a reaction with calcium hydrate, which, it is believed, is liberated from the chlorinated lime in the process, with the formation of chloroform and formate of calcium. The production of chloroform in this manner may be thus represented:

C_2H_6O	+	Cl_8	=	C_2HCl_3O	+	$5HCl$.
Alcohol.		Chlorine (from chlorinated lime).		Chloral.		Hydrochloric acid.
$2(C_2HCl_3O)$	+	$Ca2HO$	=	$Ca2CHO_2$	+	$2CHCl_3$.
Chloral.		Calcium hydrate (derived from chlorinated lime).		Calcium formate.		Chloroform.

As chlorinated lime (made by exposing slaked lime, CaH_2O_2, to the action of chlorine gas) is, as yet, an undetermined compound, any representation of its reaction with alcohol as an exact equation must be hypothetical. The essential facts are, however, as above represented.

The *National Dispensatory* (Stillé and Maisch) gives the following formulæ for the manufacture and purification of the drug:

"To prepare chloroform six parts of assayed chlorinated lime are mixed with about twenty-four parts of water, and the mixture strained into a still; one part of stronger alcohol is added, and the whole heated to 40° C. (122° F.), when the heat is nearly wholly withdrawn. The reaction now proceeds rapidly, the temperature rises, and the chloroform, mixed with some alcohol, distils over. The distillate is washed with water; the subsiding layer constitutes *crude chloroform.*

"*Purification.*—Take of commercial chloroform one hundred troyounces; sulphuric acid, twenty troyounces; stronger alcohol, twelve fluidrachms; carbonate of sodium, five troyounces; lime in coarse powder, half a troyounce; water, ten fluidounces. Add the acid to the chloroform, and shake them together occasionally during twenty-four hours. Separate the lighter liquid, and add to it the carbonate of sodium previously dissolved in the water; agitate the mixture thoroughly for half an hour, and set it aside; then separate the chloroform from the supernatant layer, and mix it with the alcohol. When the mixture has separated into two transparent layers, transfer the chloroform into a dry retort, add the lime and distil, by means of a water-bath, into a well-cooled receiver, taking care that the temperature in the retort does not rise above 67.2° C. (153° F.), until one troyounce of residue is left. Keep the distilled liquid in well-stopped bottles.—*U. S.*"

Properties.—Thus, refined chloroform is a limpid, colorless, volatile fluid, possessing a very sweet and pungent taste and an odor not unlike that of ether, but more aromatic and agreeable. Chloroform when as nearly as possible pure has a specific gravity of 1.5022. The specific gravity of the official chloroform of the *U. S. Pharmacopœia* is 1.480, this containing a little alcohol. Chloroform is not readily inflammable, but when ignited burns with a greenish, smoky flame. It is freely soluble in alcohol and ether, but only slightly soluble in water. Its own solvent powers are notable, many of the resins, the fixed and volatile oils and fats, camphor, gutta-percha, caoutchouc, such gums as benzoin, tolu, copal, and mastic—also bromine, iodine, and a large proportion of the organic alkaloids—being freely dissolved by it.

By exposure to air and sunlight chloroform is liable to undergo a slow decomposition, with the production of other combinations of chlorine, such as chloroxycarbonic or "phosgene" gas ($COCl_2$). As this is immediately decomposed in the presence of water, such a gas on entering the respiratory tract would doubtless be at once broken up into hydrochloric acid and carbonic acid ($COCl_2 + H_2O = 2HCl + CO_2$), thus forming a highly irrespirable mixture.

TESTS.—*Acids and Chlorine.*—The presence of such products of decomposition may be determined by the action of the specimen upon moistened blue litmus-paper, which will be reddened by acids and bleached by free chlorine. Chlorine or hydrochloric acid, if present, will produce, with silver-nitrate solution, a white flocculent precipitate of silver chloride.

Alcohol and Ether.—The officinal chloroform contains, as already stated, a small proportion, about 1 per cent., of alcohol; and as this is found to give stability to the preparation and prevent the formation of acids, its presence in this amount is advantageous, and cannot, to any appreciable extent, affect the anæsthetic power of the drug. The existence of a more considerable quantity will of course proportionately lower the specific gravity, which should not be below 1.480. If the chloroform contains 2 or 3 per cent. of alcohol or ether, it will cause the coagulation of albumen; this a pure chloroform will not do.

Another test is to place a drop of the chloroform in a glass of clear distilled water: the globule will sink to the bottom and remain perfectly transparent if the specimen be pure, but will become opalescent if either alcohol or ether is present in the quantity above indicated.

Methyl Compounds.—These highly dangerous contaminations, so likely to be present when the chloroform has been distilled from methyl alcohol, may be detected by shaking the chloroform and an equal bulk of pure sulphuric acid together in an absolutely clean glass-stoppered bottle, and allowing the liquids to remain in contact for twenty-four hours. If at the expiration of this time no discoloration has appeared, the specimen may be pronounced free from methylated impurities; but the development of a dark-brown or blackish color stamps it as entirely unfit for use, except in the arts, in many of which chloroform made from wood-spirit is largely consumed.

Deterioration.—Under the combined influences of sunlight and air even the best specimens of chloroform are liable in the course of time to become contaminated by the products of decomposition. To guard against this result to as great an extent as possible, the chloroform should be kept in a bottle well filled, and tightly corked to exclude air and prevent waste: this a glass stopper, unless fitted with more than ordinary nicety, accomplishes very imperfectly. When the specimen is to be kept on hand for a very long time, the bottle should be placed in dark wrappings in a dark closet to exclude light. The drug if very old should never be used without careful tests as to its purity.

Vaporization.—Chloroform is an exceedingly volatile substance, but, like other agents of its class, vaporizes much more rapidly at an elevated than at a low temperature.

Snow found that at 40° F. air would take up but 6 per cent. of chloroform vapor; at 50° F., 8 per cent.; at 60° F., 12 per cent.; at 70° F., 19 per cent.; at 80° F., 26 per cent.; and at 90° F., 35 per cent. Hence, as with ether, anæsthetic effects are produced far more quickly in a warm room than in a cold one. The vapor is more than four times as heavy as atmospheric air, and has a specific gravity of 42 at 60° F. (Snow).

PHYSIOLOGICAL EFFECTS.—*Given by the stomach,* in medicinal doses

(♏ij–♏v), taken shaken up with water or dropped upon sugar, chloroform produces simply a feeling of gentle warmth, followed by the coolness consequent upon its rapid vaporization, but when swallowed in very large doses, undiluted, it acts as a violent irritant as well as narcotic poison. The result, however, is not invariably fatal. Taylor reports a case[1] in which a man swallowed four ounces of chloroform and yet recovered. He was able to walk a considerable distance after taking the dose, but subsequently fell into a state of coma, with dilated pupils, stertorous breathing, cold skin, imperceptible pulse, and general convulsions. Recovery followed after five days.

In the case of a physician who swallowed three ounces of the drug the result was not so favorable: complete anæsthesia continued for fourteen hours; this was followed by a return to consciousness, but acute gastritis and rapid collapse ensued, the patient dying in twenty-four hours after taking the poison.

Much smaller doses, however, have caused alarming depression, and Taylor[2] reports the case of a boy four years old in whom fatal coma was caused by a single drachm of the drug. Anstie found that forty-five minims produced decidedly anæsthetic effects upon himself: this amount he took suspended in an ounce and a half of thin mucilage, "the stomach being quite empty at the time." He states that—

"Great warmth at the epigastrium and a feeling of flushing all over the body succeeded, almost at once, five minutes after taking the dose; the pulse was throbbing 100 per minute, and the heart beating with uncomfortable violence; a sense of decided confusion of mind also annoyed me. Five minutes later I experienced a considerable degree of nausea, and the pulse had fallen much lower, but it was impossible for me to speak as to its positive frequency, as I must have fallen very soon after this into a state of unconsciousness. I recovered my senses at length, and on looking at my watch found that it was forty-six minutes from the time of commencing the experiment. That it was not common sleep into which I had fallen was obvious from the fact that my lower limbs still felt heavy and numb, and on attempting to stand I tumbled down. For almost two hours after this I remained in a state of great discomfort, shivering, nauseated, and with aching pains in the head and in all my limbs, which sometimes assumed the sharpness of a twinge of neuralgia. It was some time also before I recovered my muscular sense and an accurate co-ordinating power over the movements of the limbs."[3]

There is no true chemical antidote for chloroform taken in toxic doses: artificial respiration, heat, and faradization must be resorted to, as in anæsthesia by inhalation.

Hypodermic medication with chloroform is sometimes practised, and is highly recommended by Bartholow, who was the first to propose its use in the treatment of neuralgia. His plan of treatment consists in the injection deeply in the neighborhood of the affected nerve of five to fifteen minims of pure chloroform. Prof. Bartholow states that "considerable pain is produced by this injection: swelling of the invaded tissues follows, and a circumscribed induration and numbness are left;

[1] Taylor on *Poisons*, p. 619.
[2] *Op. cit.*, p. 740.
[3] *Stimulants and Narcotics*, p. 310.

but these effects slowly disappear. An abscess may result from local inflammation, but this is not frequently the case. The author has procured by this means apparently permanent relief to long-standing cases of neuralgic pain (tic douloureux) affecting the superficial divisions of the fifth. Other practitioners have been equally successful, and the cases thus treated now include neuralgic affections of the most important nerves."[1]

Upon the skin, unless very delicate, the local effect of chloroform is not so irritant as upon mucous and subdermal surfaces; indeed, an irritant effect is not usually produced unless close contact of the fluid is maintained and vaporization is retarded or prevented. With these precautions, which may be effected by covering the skin in contact with the chloroform with some impermeable fabric, such as rubber cloth or oiled silk, good counter-irritant and slightly anæsthetic effects may be obtained. For a small area of tissue a thimble placed over the chloroform will confine the vapor and so obtund sensation that a slight puncture may be made without pain. Where more decidedly counter-irritant effects are desired the writer has for many years used a combination of chloroform, ammonia, and alcohol after the following formula:

℞. Chloroformi,
Aquæ ammoniæ fort., *āā*, f℥j;
Alcoholis, f℥iv. M.

Sig. For external application.

This makes an excellent combination: it does not stain either the person or the clothing, and is free from objectionable odor. The vapor is often grateful in headache, and the forehead or other seats of pain may be bathed in the fluid, while by confining the vapor any degree of counter-irritation may be induced, from the mildest rubefacient effect to the formation of a blister, the result being regulated by the length of time during which the escape of vapor is prevented. Thus applied, it will often be found a convenient, cleanly, and efficient substitute for a mustard plaster.

Effects by Inhalation.—The effects of chloroform vapor when inhaled are very closely analogous to those produced by the inhalation of ether. It is probable that concentrated chloroform vapor is even more irritant to the pharyngo-laryngeal tract than ether vapor at the same tension and in the same volume. This was evidenced in the experiments of the committee appointed by the Royal Medical and Chirurgical Society to investigate the effects of chloroform, and who found that air saturated with chloroform when breathed by animals produced contraction of the entire pharynx and violent and repeated acts of deglutition, while when a 5-per-cent. dilution of the vapor was blown upon the fauces no irritant effect was produced, and that after partial insensibility of the fauces was thus effected the more concentrated vapor might be inhaled without the spasmodic movements described.

Concentrated vapor is, however, dangerous at any stage of the process, the committee having observed a diminution in blood-pressure each time additional chloroform was placed in the inhaler. Heart

[1] Bartholow's *Materia Medica and Therapeutics*, p. 358.

paralysis, as the result of impressions thus made upon the laryngeal nerves, or upon the terminal branches of the pneumogastric distributed to the lungs, is now recognized as one of the most frequent causes of death in chloroform narcosis, although the specifically depressing influence of the drug upon the cardiac ganglia is doubtless an important attendant condition in such cases.[1]

Authorities differ as to the relative frequency with which vomiting occurs during anæsthesia produced by ether and chloroform respectively. Kappeler gives a result of 14 per cent. in chloroform narcosis and 25 per cent. in ether narcosis; and this perhaps fairly well represents the proportion. In the writer's experience, however, vomiting after return to consciousness—generally a much graver and more troublesome complication—occurs more frequently with chloroform than with ether; and this accords with the observation of Dr. Thomas Keith, who was led to try ether instead of chloroform in ovariotomy, and states that "whereas with chloroform vomiting was the general rule, it now seldom occurs in his practice."[2]

Chloroform, like ether, produces progressive paralysis of the nervous centres controlling intellection, movement, voluntary and involuntary, and special and general sensation. With chloroform complete narcosis is more rapidly induced than with ether, but as the great nervous tracts are narcotized in the same order and with the same symptomatic manifestations, no other very marked differentiation between the usual effects respectively of the two agents can be distinguished. A paramount point of distinction, now universally conceded, is that when chloroform is used the cardiac ganglia are far more likely to undergo paralysis than when ether is the agent employed.

Preparation of the Patient.—The details concerning the preparation of the patient, etc., already given in connection with the subject of etherization, are all applicable to the production of the anæsthetic condition by means of chloroform. No single precaution should be omitted; indeed, as chloroform is by far the more potent and dangerous drug, the care and vigilance of the operator should be redoubled; above all, as failure of the circulation is the chief danger, the reclining position must be insisted upon. Owing to the irritant effect upon delicate cutaneous surfaces of chloroform when contact is close and constant, the face of the patient, especially about the mouth and nose, should be anointed with some fatty substance as a protective shield.

Preliminary Medication.—The administration of opiates to the patient previous to the inhalation of chloroform is now the usual practice of a majority of those who rely upon that anæsthetic agent. Nussbaum of Munich in 1863 was the first to call general attention to the value of the hypodermic administration of morphia as a means of prolonging the anæsthetic state without increasing its dangers. The experiments of Claude Bernard upon the lower animals also demonstrated the fact that some of the more undesirable features of a purely chloroform narcosis were antagonized by this preliminary hypodermic injection, the two

[1] Dr. Reeve (*American Journ. Med. Sci.*, Jan., 1867) was the first to call attention to this element of danger in the administration of chloroform.

[2] Holmes's *System of Surgery*, vol. iii. p. 549.

agents appearing to be supplementary in their effects, so that a more profound and prolonged sedation could be produced with a much smaller amount of chloroform than is usually required when that agent is employed alone. In regard to its use upon the human subject, Dr. Reeve[1] makes the following statement: "Given hypodermically to the amount of from one-sixth to one-third of a grain some twenty minutes before the inhalation of chloroform, it diminishes the stage of excitement, lessens to one-half, or even one-third, the amount of the anæsthetic required, diminishes the vomiting, and promotes quiet sleep afterward. . . . . The value of this plan may be said to be now generally recognized, particularly for protracted and severe operations. It should never be omitted in cases where great dread of the operation exists, producing an emotional state which experience has shown to have played no insignificant part in the history of chloroform accidents. Tranquillized and soothed by the narcotic, such patients pass quietly into the anæsthetic state, and certainly escape risks otherwise encountered."

Prof. Gross states[2] that "this practice" (the use of opiates) "has long been in force in all my more severe clinical cases, and I have the greatest confidence in its efficacy, not only in sustaining the heart's action, which the different preparations of opium are so well known to do, but in preventing the cough, excitement, and muscular rigidity so often witnessed, especially in nervous persons."

As one of the primary physiological effects of opium and its principal alkaloid is to strengthen the action of the heart, this action continuing during a period of time relatively quite considerable—a period certainly exceeding that required for the completion of the average operation—its use in connection with chloroform would seem to be indicated on physiological grounds as well as warranted by the results of practical experience. Of recent years a combination of morphia and atropia, administered hypodermically, has been thought to produce even better results than morphia alone, the atropia, as is claimed, antagonizing far more effectually than does the opium alkaloid the inhibitory influence exerted by the pneumogastric nerve when stimulated either by shock or by the specific excitatory influence exerted by all volatile anæsthetics; to which influence the frequent vomiting and occasional cardiac arrest following their administration are by some attributed. The dose of atropia recommended is from $\frac{1}{180}$th to $\frac{1}{90}$th of a grain, to be given in combination with from $\frac{1}{12}$th to $\frac{1}{6}$th of a grain of morphia, within from about twenty to thirty minutes before the administration of the anæsthetic.

This combination has been recommended for use before ether as well as chloroform inhalations, but as the action of the heart is, as a rule, not seriously weakened by the former agent, theoretically such a combination would not seem to be demanded; neither has the fatality which has hitherto attended the use of ether been so great as to make imperative any very radical changes in existing methods for its administration.

A strong argument against unnecessary complications in anæsthesia

[1] "Anæsthetics," Holmes's *System of Surgery*, pp. 555, 556.
[2] *System of Surgery*, p. 559.

is the fact, which all practical medical men must recognize, that by a multiplication of pharmaco-dynamic influences in the giving of anæsthetics, as in medication for disease, symptoms are often obscured, masked, or confused, to the embarrassment of the surgeon or physician and the danger of the patient. Untoward manifestations attending the use of a single toxic agent, when the modes by which its properties are manifested and the direction in which its force is expended are clearly understood, may be antagonized much more readily and with much greater assurance of success than when many such potencies, assailing by as many different lines of attack, are to be met and overcome. Ether may at some future time be made even safer than it now is, but it may be unhesitatingly affirmed that that result has not been accomplished by any anæsthetic combination yet devised. Chloroform might well be made less dangerous, and that combinations with morphia or atropia, singly or together, are means to this end would seem to be the general verdict of those who practise those forms of mixed anæsthesia.

The administration of alcoholic stimulants previous to chloroform narcosis is also highly commended by many; and as alcohol, for a time at least, except in excessive doses, stimulates cardiac action, its use, too, would appear to be theoretically correct. For this form of stimulation brandy or whiskey is usually given, in doses of from half a fluidounce to two fluidounces, diluted, about ten minutes before the administration of the anæsthetic begins.

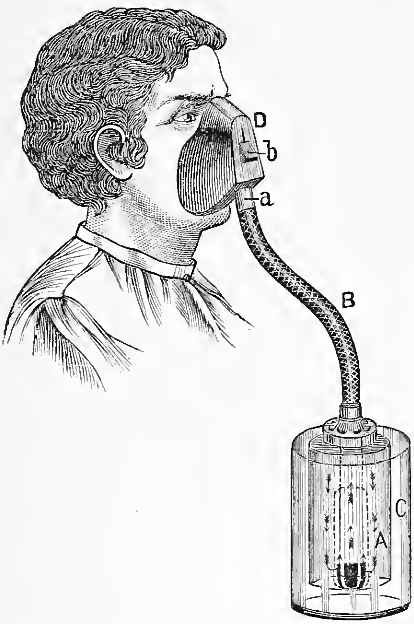
Mode of Administration.—*Inhalers.*—As chloroform is a drug of great potency, its vapor can be safely inhaled only when largely diluted with air. At 70° F. air, as has been seen, is capable of holding in suspension 19 per cent. of chloroform vapor—a proportion much too large for anæsthetic purposes, from 3½ to 4 per cent. being found to give the best results. To secure and maintain this exact dilution is a matter of no small difficulty, and a large number of inhalers have been introduced for this purpose. That of Dr. Snow was probably the first to be devised and used.

Snow's Inhaler.—Snow's inhaler consisted of a mouthpiece or mask provided with valves, the mask communicating by tubing about a foot long and three-quarters of an inch in diameter with an apparatus in which the air became charged with chloroform vapor by passing over and through coils of bibulous paper wet with the drug, the temperature of the vapor being regulated by a water-bath, which was a part of the appliance. This apparatus is figured by Snow in his work on anæsthetics (p. 82). A better illustration, however, is that seen in Fig. 8.[1] The inhaler consists of double cylinders of metal, the outer of which (C) contains water at the ordinary temperature of the room, the purpose of this being to prevent that cooling of the entire apparatus which would otherwise result from the vaporization of the chloroform, such a reduction in temperature being undesirable, owing to the retarding influence it would exert upon the evaporation of the anæsthetic. The inner cylinder (A) is the vaporizing chamber. Within it there is screwed a frame provided with numerous openings for the admission of air and having four stout wires which descend nearly to the bottom of the cylinder. These

[1] From Kappeler, *Anæsthetica*, p. 140.

wires are for the support of two coils of bibulous paper, which are tied around them and reach fully to the floor of the cylinder. In the lower part of these coils of paper four notches are cut to allow the air to pass in the direction indicated by the arrows; that is, through the openings seen in the top of the cylinder outside of the paper coils, then beneath them, through the four notches, then upward inside the paper coils, saturated with chloroform, to and through the elastic tube (B) communicating with the mouthpiece (D).

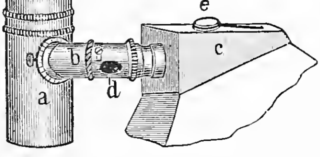
Fig. 8.



The chloroform to be vaporized, about two and a half fluid-drachms, is placed in the bottom of the cylinder. Care should be taken not to introduce enough of the fluid to fill the notches cut in the paper coils for the transmission of air. Kappeler recommends that a layer of bibulous paper be placed also in the bottom of the cylinder; which is a good suggestion, as thereby the chloroform would be more fully and readily absorbed, and its vaporization be thus more gradually and equably effected.

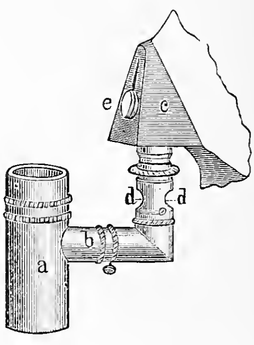
The mouthpiece represented in the cut is the invention of Dr. Francis Sibson. It was originally made of some pliant material, such as leather or sheet lead, although if now used flexible rubber would probably be em-

Fig. 9.



Sansom's Inhaler adapted to the recumbent position.

Fig. 10.



Sansom's Inhaler adapted to the sitting position.

ployed. It contains two valves: one of them is placed at its point of connection (*a*) with the elastic tube. This valve opens during inspiration and closes during expiration. The second valve (*b*) is in front of the mouthpiece, and opens during expiration and closes during inspiration.

During the earlier stages of the administration of chloroform by this inhaler the expiration valve (*b*) can be held partly open, thus permitting the entrance of pure atmospheric air and diluting to any required extent the chloroform vapor passing from the inhaler through the inspiration valve (*a*). Dr. Snow claimed that with this inhaler air at the ordinary temperature of about 60° F. would take up about 5 per cent. of chloroform vapor.

Sansom's Inhaler.—The inhaler of Dr. Snow proving in practice to be somewhat cumbersome and othewise unsatisfactory, Dr. Arthur Earnest Sansom devised the more convenient apparatus represented in Figs. 9 and 10. The construction and mode of using this inhaler are thus described by Dr. Sansom:[1]

"The receptacle for the chloroform is a small metallic cylinder, its height about three inches, its diameter about an inch and a half. It is filled with blotting-paper loosely crumpled, or, what is better, a rolled piece of lint; at the top it is provided with a freely-perforated plate for the admission of air and for the introduction of liquid chloroform. An exit-tube passes at right angles from this receptacle, it being attached a little above the centre, so that a cup may be kept for the retention of any liquid chloroform which may be more than sufficient to moisten the blotting-paper or lint. Thus arranged, a direct current of air in inspiration passes through the apertures over the chloroform, and of course carries the vapor along with it.

"The next requisite was to supply an equality of temperature. I found this object fulfilled sufficiently for all practical purposes by surrounding the metallic cylinder with a stratum of gutta-percha. I found that a cylinder of equal size with that of Dr. Snow's cylinder, and surrounded with gutta-percha as Dr. Snow's is with water, allowed even a greater percentage of vapor to be given off than the latter did. Thus in my experiments after twenty inspirations in case of the cylinder surrounded with water, 30.04 cubic inches of vapor passed; in case of the cylinder surrounded with gutta-percha, 36.4 cubic inches passed.

"But, as I have before said, the difficulty is not so much in keeping up this high proportion as in preserving it sufficiently low. I fulfilled the indication of diminishing the proportion by reducing the cylinder in size and bulk; and I was led to consider that the value of the gutta-percha was not so much to keep the chloroform warm, as it were, but rather to prevent the metallic surface from getting too warm from being held in a hot hand.

"It was thought much more convenient to abolish the long flexible tube. The exigencies of mobility were to be provided for; a very simple arrangement accomplished this. The exit-tube was again bent at a right angle before ending at the mouthpiece. Thus the instrument was adapted to a patient in the sitting position, and the tube being freely movable at the place of adaptation of the mouthpiece, the cylinder could be turned to the right or left as required. To make the whole instrument adapted to the recumbent position, it was only necessary to make provision for a rotatory movement in the horizontal part of the exit-tube. Thus the chloroform-containing cylinder could be always retained upright. There was no

[1] *Chloroform, its Action and Administration,* pp. 188–191.

necessity for a flexible tube; for by the double movement of the receptacle on the exit-tube and of this tube on the facepiece any position was provided for. The receptacle was always preserved upright, so that no chloroform could be spilled, and any movement of the patient, however brisk, could be followed in a moment.

"In that part of the tube which terminated in the facepiece I caused to be introduced an arrangement by which a supply of air could be turned on or cut off at pleasure. The tube here is double, an external rotating upon an internal: both are perforated, front and back. Thus in one position air enters freely; by slightly turning the outer tube the apertures are partially closed, and by turning it still more they are covered completely; the unperforated portions of one tube cover the perforations of the other.

"The facepiece is the same as Dr. Sibson's, but it freely turns upon the tube of the inhaler.

"The receptacle being supplied with blotting-paper or lint, and a little piece being also laid along the horizontal part of the tube so as to act as a siphon, a drachm and a half of chloroform is poured into it. This quantity is usually sufficient, as there is so little waste. The outer movable tube near the facepiece is so turned that the holes in it are coincident with the holes of the inside tube; consequently, unimpeded currents of air enter. Moreover, the valve of the facepiece is turned away from its aperture. The patient, being now allowed to inhale, breathes so much atmospheric air that the taste of chloroform barely reaches him. The outer tube is then turned so as to cut off in a slight degree the entrance of air, and this is done every two or three inspirations, until, the apertures being closed, no air enters by these channels. Still, the aperture of the facepiece allows the entry of air. This expiratory valve being made gradually to cover its aperture, the patient breathes a sufficient proportion of chloroform perfectly to induce anæsthesia.

"The process is thus a gradual one from the beginning until such time as the patient is able to breathe an atmosphere of 5 per cent. There is no cough, no struggling, no resistance, but the patient succumbs to the chloroform sleep gradually and imperceptibly."

Clover's Inhaling Apparatus.—The late Mr. Clover of England, realizing the desirability of securing for inhalation a fixed and definite dilution of the chloroform vapor in atmospheric air, reintroduced a method first suggested and tried by Dr. Snow, that of introducing into a bag or balloon of known size a measured quantity of chloroform, filling the balloon with air, and allowing the patient to inhale from it through a mouthpiece provided with a valve to prevent the return into the balloon of the products of expiration. In regard to this method Dr. Snow says:[1]

"I tried this plan in a few cases in 1849, with so much chloroform in the balloon as produced 4 per cent. of vapor in proportion to the air. The effects were extremely uniform, the patients becoming insensible in three or four minutes, according to the greater or less freedom of respiration; and the vapor was easily breathed, owing to its being so equally mixed with air. I did not try, however, to introduce this plan into general use, as the balloon would sometimes have been in the way of the surgeon, and filling it with the bellows would have occasioned a little trouble. It seemed

[1] *Anæsthetics*, p. 80.

necessary to sacrifice a little of absolute perfection to convenience, and I therefore continued the plan I had already followed."

The apparatus used by Mr. Clover is represented in Fig. 11, and is thus described by Dr. Sansom:[1]

Fig. 11.

Clover's Inhaling Apparatus.

"The apparatus he employs is, first, a bag for containing the anæsthetic mixture; secondly, an arrangement for filling the bag with a certain proportion of chloroform and air. The bag is of a large size, capable of containing sufficient of the chloroform atmosphere to serve for several cases of inhalation. It is lined with a film of a material (such as goldbeater's skin) which is capable of resisting the solvent action of chloroform. A flexible tube leads from the bag to the mouthpiece, which is of the same conformation as Dr. Sibson's; but Mr. Clover has introduced an improvement by using for the valves thin plates of ivory supported by spiral springs. The india-rubber which is usually employed for the valves is apt to curl up.

"The apparatus for filling the bag with the atmosphere for inhalation consists of a bellows shaped like a concertina, with a receptacle for a definite amount of chloroform attached to its nozzle. This receptacle is a metallic box, which is kept warm by an interstratum of hot water, so as to facilitate the evaporation of the chloroform, which is received on blotting-paper in its interior. The lid of the box contains an aperture for the reception of a graduated syringe, by which the chloroform is supplied. Opposite

[1] *Op. cit.*, pp. 179–182.

that part of the box to which the nozzle of the bellows is attached is an open tube, to which the bag can be adapted. The apparatus being thus connected, air is blown over the chloroform into the bag by means of the bellows. For each thousand cubic inches of air which the bellows throws in, forty minims of chloroform are supplied by means of the syringe. Thus, since forty minims of chloroform produce about forty-five cubic inches of vapor, the atmosphere in the bag contains 4½ per cent. of chloroform vapor. Of course the percentage is determined at will by the amount of chloroform supplied.

"When sufficient of the atmosphere has been thus prepared, the bag is detached from the metallic box and the mouthpiece applied. It is then suspended in a convenient position from the collar of the administrator's coat. The position of administrator and patient is seen in the engraving (Fig. 11).

"In commencing the inhalation free air is introduced by an aperture (near the facepiece) which can be gradually closed as the patient becomes accustomed to the vapor.

"I consider this to be the safest method of all for the administration of chloroform. Mr. Clover in a letter to myself states, 'I have found my inhaler produce the anæsthesia more uniformly than I have been able to effect by any other means. Patients very rarely cough or make any manifestation of the vapor being too pungent. A large majority of the patients are prepared for the commencement of the operation in less than six minutes, and they certainly recover from the effects of chloroform more readily and with less sickness and prostration than I have observed when I did not make use of the inhaler.'

"For myself, speaking theoretically, I believe that this means obviates the most urgent objection to chloroform administration, and is especially useful when patients are assembled together ready to be operated on one after another. The most potent objections to it are the somewhat cumbrousness of the reservoir, the necessity of employing some little time in making the mechanical arrangements for the production of the atmosphere, and, lastly, the expensiveness of the apparatus. Though of great value to those who are accustomed to administer chloroform, it is scarcely to be expected that every practitioner would provide himself with an apparatus of this sort."

Paul Bert's Method.—What was practically the same method as that of Snow and Clover was subsequently adopted by the late Prof. Paul Bert of Paris, who in 1883 called the attention of the Biological Society of that city to a method of anæsthesia by chloroform which to him appeared to possess absolute security.

The following is Prof. Bert's account of his experiments with the method upon animals:[1]

"I commence by putting an animal rapidly to sleep with a mixture of twelve grammes of chloroform vaporized in one hundred liters of air. Anæsthesia is produced very rapidly and almost without reaction. Then by opening a stopcock I cause the dog to breathe a mixture consisting of eight grammes of chloroform in one hundred liters of air. This mixture, which if used alone would have produced the anæsthetic sleep very slowly and imperfectly, serves to maintain the insensibility secured by the stronger mixture. I have thus been able to keep dogs insensible during three hours

[1] See *Comptes rendus des Séances et Mémoires de la Société de Biologie*, séance du 16 Juin, 1883.

and a half without any trouble with the respiration or circulation. With twelve grammes for one hundred liters of air they would be dead in about an hour and a half.

"This very simple method, which requires for apparatus only two sacks of caoutchouc, to me appears at the same time very harmless and very easy to put in practice."

Six months later, in a communication to the Biological Society,[1] M. Bert announced the successful application of his method to the human subject. In this communication he says:

"The first application of the method was made December 21, at the Hôpital Saint Louis, during the service of Dr. Péan. The experiment was conducted by Dr. Dubois, assistant in my laboratory. It succeeded perfectly. The mixture of eight grammes of chloroform in one hundred liters of air has from the first given excellent results. . . . . In one case anæsthesia was continued during twenty-eight minutes, during which only fifteen grammes of chloroform were used. . . . . The mixture of eight in one hundred is very readily tolerated: the resistance which is ordinarily offered by patients to the inhalation of anæsthetic vapors was not made. The state of dilution of the vapor shielded from irritation the nerves of sensation in the respiratory passages: there was no cough, no spasm, no suffocation, no spasm of the diaphragm, or efforts at vomiting in the early stages of the inhalation. Two of the patients had eaten before the operation, but they had only a few qualms of nausea after its completion.

"The anæsthesia is regular in its progression: if a longer time is required than where the more concentrated vapor is used, there is not the preliminary period of violent agitation ordinarily observed. Finally, the patient after the cessation of the inhalation remains asleep during a period of time sufficient to effect the painless dressing of the wound: the awakening is always calm, sometimes gay.

"As to the economy of the process, the quantity of chloroform required is much less than by ordinary methods, an average of from fifteen to twenty grammes being used in operations of from fifteen to twenty minutes' duration. The vapors which spread around the patient are much less disagreeable than those which escape from the inhaler in the old process."

Dr. A. Aubean[2] states that up to February, 1885, two hundred patients had been operated upon during the service of Dr. Péan in the Hôpital Saint Louis, with results confirming the value of the method. According to the same authority, Prof. Bert subsequently somewhat modified the proportions of his mixture by beginning with ten grammes of chloroform in one hundred liters of air, and when anæsthesia was complete giving eight in one hundred, afterward maintaining the anæsthetic state by a mixture containing six grammes in one hundred.

Several changes also were made in the combining and inhaling apparatus. The sacks of caoutchouc were replaced by a device of Dr. Saint Martin, which consisted of two gasometers, one of which was filled while the patient inhaled from the other. Two assistants were required for its management. For this reason, and because the tubes and valves were liable to get out of order, "constituting a permanent danger," Dr.

[1] Séance du 22 Decembre, 1883: "Application à l'Homme de la Méthode d'Anæsthesie chloroformique par les Mélanges titrés."

[2] *L'Odontologie*, Février, 1885.

Raphael Dubois substituted for it a contrivance of his own, consisting of two telescopic gasometers, each with a capacity of a hundred liters, one assistant being sufficient for their operation. This too was found unsatisfactory and unreliable, and Dr. Dubois had constructed the appa-

Fig. 12.

Anæsthetic Apparatus of Dr. Dubois.

ratus represented in Fig. 12, in which gasometers were entirely dispensed with, and of which he gives the following description:[1]

"The anæsthetic machine consists of an air-pump, recalling the form known in hydraulics under the name 'pompes des prêtrés.' A horizontal circular plate supporting an invaginated membrane is put in movement through the action of a shaft terminated at its upper part by a Vaucanson chain reflected over a toothed wheel and supporting at its free extremity a counterweight.

"This toothed wheel is put in movement by a cog-wheel to which is communicated an alternate circular movement, limited in each direction by an attachment controlling at each end of the course a slide-valve similar to those used in steam-engines, thus avoiding the use of valves self-acting under pressure, whose action is often imperfect, and, as a consequence, disquieting.

"The working of this part of the mechanism is invariably given to the person to whom is entrusted the measurement of the dose of the liquid anæsthetic. To this end a small perforated metallic vessel, operating like a *godet de noria*, passes at each stroke of the piston the desired quantity of the anæsthetic employed into a receptacle placed beneath it. The *godet*,

[1] *L'Odontologie*, August, 1884.

having arrived at the culminating point of its course, empties its contents into a mixing-chamber traversed by the air drawn from the exterior by the movement of the piston.

"The volume of air, measured by the capacity of the body of the pump, is always sufficient to volatilize completely the liquid anæsthetic, the vapors of which mix intimately with the air at the moment of its passage into the mixing-chamber.

"The air-pump has a double action: thus the apparatus may be charged upon one side of the piston, while upon the other side the prepared mixture is conducted to the respiratory passages of the patient by a flexible tube, to which may be adapted either a mask made after a special model, without valves, or, if desired, a tube through which the anæsthetic mixture may be injected into the back part of the mouth."

Still further details in regard to this apparatus are given in *L'Odontologie*,[1] as follows:

"As one turn of the crank corresponds to the introduction of about twenty liters of air, it will be seen that in a majority of cases the crank may be turned quite slowly; after several turns have been made a sense of resistance will be felt, due to the fact that the piston has terminated its course. The crank is then turned in the opposite direction, so that the two faces of the piston may be alternately evacuated; in each movement the termination of the course is indicated by a very sensible resistance.

"All the other functions of the machine—placing of the chloroform, dosage, distribution of the mélange upon the two faces of the piston, etc.—are entirely automatic, and invariably dependent upon the movement of the crank. . . . .

"The inhaler is made in two different forms, the one to be used when the anæsthetic mixture is to be inhaled in the ordinary manner, the other available when it is desirable to deliver the anæsthetic into the back part of the buccal cavity or pass it through the naso-pharyngeal passages, as may be done in operations in the mouth or upon the face.

"In such cases this apparatus renders very great service, for its use makes possible the injection of the exactly proportioned anæsthetic mixture directly into the bronchial passages, and the maintenance of an anæsthesia more profound and continuous than can be obtained by any other method. The mixture is carried to any desired distance by means of a special metal tube which accompanies each machine, and which may at the same time play the part of a tongue-depressor and prop for keeping the jaws apart. . . . .

"The inhaling mask has no valves: it is so arranged that the patient always remains in the presence of a definitely proportioned anæsthetic atmosphere, in which he can respire as freely as under ordinary conditions. An accident happening to the machine or inhaling-tube could result in no other possible inconvenience than the patient's deprivation of the anæsthetic mixture: he could still breathe freely by means of the orifice through which he expires when the machine is in movement, and which at all other times remains open."

Merits of Inhalers.—As to the practical merits of either the Clover apparatus or that of Dr. Dubois the writer has had no opportunity of determining by personal observation; but concerning the value of the

[1] February 1885, pp. 59–61.

principle of the definite dilution of chloroform vapor which they are designed to secure there can be no question ; for, as has been previously stated, it has been fully demonstrated, both by unfortunate clinical experience and by physiological experimentation, that concentrated chloroform vapor either in the early or later stages of anæsthesia is capable of producing not only spasm of the glottis, but paralysis of the heart by the sudden irritation of the branches of the par vagum in the lungs.

Sansom[1] remarks on this point: "I recognize two principles for attaining the maximum of safety in chloroform administration:

"I. The continuous inhalation of an atmosphere of known strength—an atmosphere of about 3½ per cent. We may call this the principle of definite dilution.

"II. The administration of an extremely dilute atmosphere at first, and the progressive increase in its strength, never overpassing 5 per cent. We may call this the principle of tolerance."

Dr. Snow[2] says that "if there be too much vapor of chloroform in the air the patient breathes, it may cause sudden death, even without previous insensibility and while the blood in the lungs is of a florid color."

As without some such apparatus as that either of Clover or Dubois it is practically impossible to maintain a perfectly definite and uniform dilution of chloroform vapor in the atmospheric air inhaled by a patient, it would seem to be but the part of common prudence to throw around the administration of the drug all possible safeguards, and not allow the desire to save "a little trouble," which Dr. Snow states (see p. 115) was his only reason for sacrificing "a little of absolute perfection to convenience," to weigh against considerations of safety for the patient.

The fact that the inhaling mask attached to the vaporizing-machine of Dr. Dubois is without valves is much in its favor, as their disarrangement is always among the possibilities and has frequently led to serious consequences.

The frequent occurrence of such accidents, and the numerous deaths which have followed the administration of chloroform even when given in exact and correct dilution, have created prejudices which in this country at least have led to the almost entire abandonment of any apparatus of the kind above described—a result which, if chloroform is to be administered at all, is to be regretted, as, while such inhalers do not by any means secure the safety of anæsthesia with this drug, they certainly diminish its dangers.

Usual Mode of Administration.—The plan of administration now generally adopted is to drop the chloroform, about a drachm at a time, upon a piece of lint or a handkerchief or napkin folded into a small open cone, or, as some prefer, into a square. Dr. Reeve uses a cup-shaped piece of sponge fitting over the mouth and nose, the sponge being moistened with water before the chloroform is dropped upon it: by gentle pressure the chloroform is carried to the interstices of the sponge, which thus serve as vaporizing surfaces.

Whatever form of carrier is used, it is desirable that for the first few inhalations the patient should breathe only very dilute vapor, and to this

[1] *Chloroform, its Action and Administration.*

[2] *Anæsthetics*, p. 79.

end the carrier should be held three or four inches above his face, in order that full diffusion of the chloroform in the air may be effected before entrance into the respiratory tract: by this care any considerable local irritation may be avoided, and gradually, as the respiratory surfaces become locally anæsthetized, the chloroform-carrier may be brought to within an inch of the patient's face, and thus stronger dilutions be inhaled.

Snow claims that when chloroform is thus given the air breathed by the patient will at the temperature of 70° F. contain 9.5 per cent. of vapor—more than double the proper proportion. Lister, however, who rejects "all complicated apparatus," gives different results: he found that for the first half minute, the air being at 70° F., chloroform was given off from the lower surface of the carrier, or that next the patient's face, at the rate of 24 grs. per minute. Estimating the amount of air inhaled in a minute at 400 cubic inches, and taking Dr. Snow's computation that 20 grs. of chloroform correspond to 15.3 cubic inches of vapor, 4.5 per cent. was ascertained to be the proportion of chloroform to inspired air thus obtained.[1]

These results are, however, purely theoretical. It is self-evident that in practical anæsthesia by this method the percentage of chloroform in the air is a constantly varying one, and may at any moment be too great for safety. Indeed, Lister's only guide as to the strength of the dose administered is the behavior of the patient: if the patient coughs, he regards the vapor as too strong, and withdraws the carrier farther from the face.

Braine's Method.—As indicating a possible factor in the fatal results which have followed the administration of chloroform in certain cases, the following suggestions of Mr. Braine[2] are of value in this connection:

"In looking over the history of the recorded deaths from this anæsthetic, I have been struck by the fact that many of them took place immediately after the addition of a small quantity of the anæsthetic. I think the explanation is that when the facepiece is removed for the purpose of a fresh supply, even though the patient be quite insensible, the stimulation of the fresh air unloaded with vapor causes a deeper breath to be taken, and this being followed by a more complete expiration, the following inspirations are proportionately deeper ones; and on the facepiece being reapplied more chloroform vapor is inhaled than in any previous breath; and not only this, but it is drawn at once into the bases of the lungs. If this be the true explanation, then it clearly points out our line of practice, and shows us that we should never remove the inhaler, but pour chloroform on it while on the patient's face; or, if we do take it away, it must never be replaced within an inch of the face for the first two or three inspirations, thus giving the lungs time to resume their old degree of expansion."

Time and Quantity.—As has already been stated, the physiological effects ordinarily observed in anæsthesia produced by ether and chloroform respectively are precisely analogous, and, as they have already been fully described in this paper, any detailed recapitulation of those effects is unnecessary. The same tests used in ether narcosis may be

[1] Holmes's *System of Surgery*, pp. 528, 529.
[2] *Journal of the British Dental Association*, December, 1884.

applied to determine the full development of the anæsthetic condition from chloroform. Owing to its greater potency, however, a much smaller amount of vapor and a shorter period of time is required to produce anæsthesia with chloroform than with ether.

Surgeon-major J. H. Porter gives the following report of twenty-one cases of chloroform narcosis:[1]

CHLOROFORM.

	Min.	Sec.
Shortest time taken to place under influence	2	30
Longest time " " " "	14	30
Average time " " " "	6	24
Average time under influence	12	48

Smallest quantity used in any one case	1 dr.	
Largest quantity " " "	8 "	
Average quantity " " "	3 "	9 min.

Vomiting occurred in two cases during or after administration of the drug.
Excitement occurred in ten cases during or after administration of the drug.
Great prostration in one case after administration.

SIGNS OF DANGER.—These, as already stated, are to be looked for rather upon the side of the circulation than of the respiration, although not infrequently the respiratory function appears to be primarily involved. Sansom[2] embraces in the following table a synopsis of dangerous symptoms developed in sixty-four cases of chloroform narcosis, and the relative frequency with which they occurred:

"Cessation of pulse	19
(*Concurrent signs*, muscular contraction, vomiting, relaxation of sphincters. In two cases only the pulse showed signs of failure before actually stopping.)	
Pallor of face and lips	11
Cessation of hemorrhage from wound	2
Vomiting, followed by immediate death	2
Muscular excitement	15
(Starting, endeavor to rise up, opisthotonos, epileptiform convulsion, trismus, in many cases accompanied by lividity of countenance.)	
Embarassed respiration	13
(Labored, irregular, or profoundly stertorous.)	
Cessation of pulse and respiration simultaneously	2"

Dr. Anstie[3] states that the number of cases in which, under his own hands, alarming symptoms occurred during chloroform narcosis was twenty-one out of a total number of three thousand and fifty-eight administrations. The leading details of these twenty-one cases he gives in the tables on pp. 123 and 124.

TREATMENT OF DANGEROUS SYMPTOMS.—Artificial respiration, heat, faradization or galvanism, stimulant enemata, atropia—indeed, all the agencies described in connection with the subject of etherization—are equally applicable to the treatment of dangerous complications arising in chloroform narcosis.

Nélaton's Method.—When, however, arrest of the heart's action is the primary and chief source of danger, the remedial measure most urgently demanded would appear to be the inversion or partial inversion of

[1] Erichsen's *Surgery*, p. 61.
[2] *Chloroform, its Action and Administration*, p. 132.
[3] *Stimulants and Narcotics*, pp. 324–326.

	Subject.	Nature of Operation.	Period of Occurrence of Symptoms.	Nature of Symptoms.	Duration of Symptoms.	Mode of Administration.
1	Child, æt. 2 years.	Circumcision.	3 minutes from commencement of inhalation.	Weak, fluttering pulse; gasping respiration; great pallor. Sudden.	15 minutes.	ʒj on a handkerchief.
2	Child. æt. 6 months.	Harelip.	2 or 3 minutes from commencement of inhalation.	Flickering, unrhythmical pulse; gasping breathing; livid lips. Sudden.	10 minutes.	ʒj on a sponge.
3	Man, æt. 40 years.	Hemorrhoids.	End of operation; on a second application after partial recovery.	Sudden arrest of pulse and breathing; livid lips; jaw dropped.	25 minutes.	Snow's inhaler, ʒiij and ʒiss. (Artificial respiration.)
4	Lady, æt.52 years.	Amputation for cancer of breast.	Middle of the operation; but little blood lost.	Sudden intermittence of pulse; great pallor.	5 minutes.	ʒj on a handkerchief.
5	Lady, æt.32 years.	Varicose aneurism of lip and cheek.	Less than half a minute from the commencement of inhalation.	Sudden intermittence of pulse; pallor; labored respiration.	10 minutes.	ʒj on a sponge.
6	Man, æt. 60 years.	Hemorrhoids.	Near the end of the operation.	Sudden pallor; flickering, running pulse.	7 or 8 minutes.	ʒiij in Snow's inhaler, then ʒss on lint.
7	Girl, æt.?	Removal of lower jaw.	3½ minutes after commencement. 1 minute after induction of full anæsthesia.	Sudden flickering of pulse; slow and gasping respiration: great pallor.	5 minutes.	ʒij on lint. (Rapid anæsthesia.)
8	Girl, æt. 19 years.	Plastic operation on face.	After a very few deep inhalations.	Sudden pallor; livid protruded tongue; slow, gasping respiration.	5 or 6 minutes.	ʒij on lint.
9	Man, æt. 38 years.	Radical cure of hernia.	Middle of the operation.	Sudden pallor; very hurried, weak pulse (no large hemorrhage).	A few minutes (very sick for some hours).	ʒij in Snow's inhaler, afterward ʒss on lint.
10	Man, æt. 40 years.	Lithotomy.	2 minutes from the beginning of inhalation.	Irregular, weak pulse; deadly pallor.	12 minutes.	ʒj on lint.
11	Man, æt. 22 years.	Amputation of forearm.	After a few inspirations.	Sudden insensibility; pallor; failure of pulse.	10 minutes.	ʒj on lint.

	Subject.	Nature of Operation.	Period of Occurrence of Symptoms.	Nature of Symptoms.	Duration of Symptoms.	Mode of Administration.
12	Man, æt. 43 years.	Fatty tumor removed from shoulder.	Inhalation continued for 6 minutes.	Extreme dilatation of pupils; stertorous, gasping breathing; pulse pretty regular.	4 minutes.	ʒij in Snow's inhaler.
13	Man, æt. 31 years.	Circumcision.	Middle of operation.	Sudden pallor and failure of pulse, *then* of respiration.	6 minutes.	ʒj on lint; two additional doses of ʒss each.
14	Woman, æt. 29 years.	Removal of scirrhous breast.	After a few inspirations.	Extreme pallor; intermittent pulse.	5 minutes.	ʒj on lint.
15	Girl, æt. 22 years.	Necrosis.	After a few inspirations.	Faintness; hurried respiration.	3 minutes.	ʒj on lint.
16	Boy, æt. 15 years.	Lithotomy.	1 minute from formation of complete anæsthesia.	Sudden pallor and failure of pulse.	5 minutes.	Lint. ʒj first, then ʒss additional.
17	Woman, æt. 32 years.	Plastic operation on perineum.	1½ minutes from commencement of inhalation.	Simultaneous failure of pulse and breathing; jaw fallen.	20 minutes. (Artificial respiration.)	ʒj on lint.
18	Man, æt. 56 years.	Perineal section.	Just after formation of anæsthesia.	Sudden pallor; failure of pulse; livid lips; gasping respiration.	15 minutes.	Lint. ʒj and ʒss additional.
19	Woman, æt. 42 years.	Removal of scirrhous breast.	Sudden and violent epileptiform convulsion at end of 1st minute of inhalation.	Pallor; pulse very weak after fit.	8 minutes.	Weiss's inhaler. (Out of order.)
20	Woman, æt. 37 years.	Removal of breast.	2 minutes from commencement of inhalation.	Sudden pallor; failure of pulse; respiration gasping.	3 or 4 minutes.	ʒj on lint.
21	Man, æt. 21 years.	Evulsion of toe-nail.	Middle of operation.	Sudden pallor; gasping respiration: fluttering pulse.	20 minutes.	ʒij and ʒss on lint. (Artificial respiration.)

the patient. This is a procedure which has long been advocated by the distinguished Nélaton, whose view is that syncope from chloroform is always due to cerebral anæmia, and that, the heart having ceased action, the best method of securing a return of blood to the brain is to place the patient in such a position that it must flow there by gravity. Nélaton's attention was first called to the efficacy of this method by observing that rats, which in the course of experimentation he had apparently killed with chloroform, recovered upon being carried by their tails out of his laboratory. Their resuscitation he attributed to the pendent position in which they were thus placed; and the correctness of his theory has received frequent confirmations in its application to the human subject.

Sims's Case.—An exceedingly interesting account of one of these cases is given in a paper read by the late Dr. J. Marion Sims at the annual meeting of the British Medical Association, held August, 1874, at Norwich. The patient is described as being young and beautiful, and a member of an old and titled French family. As the result of her first accouchement a vesico-vaginal fistula had formed, upon which Dr. Sims was called to operate. His coadjutor was M. Nélaton; Dr. C. J. Campbell, the obstetrician, was selected to administer the chloroform, and there were present besides Drs. Beylard, Johnston, and Mr. Herbert. The operation was performed November 19, 1861, at St. Germain, near Paris. The following forms a part of the account given by Dr. Sims of the syncope and resuscitation of his patient:

"Many years ago I imbibed the conviction of my countrymen against chloroform in general surgery, and have always used ether in preference, never feeling the least dread of danger from it under any circumstances. It is otherwise with chloroform, and in this particular case I felt the greatest anxiety, frequently stopping during the operation to ask Dr. Campbell if all was going on well with the patient. At the end of forty minutes the sutures (twelve or thirteen) were all placed and ready to be secured, and I was secretly congratulating myself that the operation would be finished in a few minutes more, when all at once I discovered a bluish, livid appearance of the vagina, as if the blood was stagnant, and I called Dr. Johnston's attention to it. As this lividity seemed to increase, I felt rather uneasy about it, and I asked Dr. Campbell if all was right with the pulse. He replied, 'All right! go on.' Scarcely were these words uttered when he suddenly cried out, 'Stop! stop!—no pulse, no breathing;' and, looking to M. Nélaton, he said, 'Tête en bas, n'est-ce pas?' Nélaton replied, 'Certainly; there is nothing else to do.' Immediately the body was inverted, the head hanging down, while the heels were raised high in the air by Dr. Johnston, the legs resting one on each of his shoulders; Dr. Campbell supported the thorax. Mr. Herbert was sent to an adjoining room for a spoon, with the handle of which the jaws were held open, and I handed M. Nélaton a tenaculum, which he hooked into the tongue and gave in charge to Mr. Herbert, while to Dr. Beylard was assigned the duty of making efforts at artificial respiration by pressure alternately on the thorax and abdomen. M. Nélaton overlooked and ordered every movement, while I stood aloof and watched the proceedings, with, of course, the most intense anxiety. They held the patient in this inverted position for a long time before there were any manifestations of returning life. Dr. Campbell in his report says it was fifteen minutes and that it seemed an age. My notes of the case, written a few hours afterward, make it twenty minutes. Be this as it may, the time was so long that I thought it useless to make any further efforts, and said, 'Gentlemen, she is certainly dead, and you might as well let her alone.' But the great and good Nélaton never lost hope, and by his quiet, cool, brave manner he seemed to infuse his spirit into his aids. At last there was a feeble inspiration, and after a long time another, and by and by another, and then the breathing became pretty regular, and Dr. Campbell said, 'The pulse returns, thank God! She will soon be all right again.'

"Dr. Beylard, who always sees the cheerful side of everything in life, was disposed to laugh at the fear I manifested for the safety of our patient. I must confess that never before or since have I felt such a grave responsibility. When the pulse and respiration were re-established M. Nélaton ordered the patient to be laid on the table. This was done gently, but what was our horror when, at the moment the body was placed horizontally, the pulse and breathing instantly ceased! Quick as thought the body was again inverted —the head downward and the feet over Dr. Johnston's shoulders—and the same manœuvres as before were put into execution. Dr. Campbell thinks that it did not take such a long time to re-establish the action of the heart and lungs as in the first instance. It may have lacked a few seconds of the time, but it seemed to me to be quite as long, for the same tedious, painful, protracted, and anxious efforts were made as before; but, thanks to the brave men who had her in charge, feeble signs of returning life eventually made their appearance. Respiration was at first irregular and at long intervals; soon it became more regular, and the pulse could then be counted, but it was very feeble and would intermit. I began again to be hopeful, and even dared to think that at last there was an end of this dreadful suspense, when they laid her horizontally on the table again, saying, 'She is all right this time.' To witness such painful scenes of danger to a young and valuable life, and to experience such agony of anxiety, produced a tension of heart and mind and soul that cannot be imagined. What, then, must have been our dismay, our feeling of despair, when, incredible as it may seem, the moment the body was laid in the horizontal position again the respiration ceased a third time! The pulse was gone and she looked the perfect picture of death. Then I gave up all for lost, for I thought that the blood was so poisoned, so charged with chloroform, that it was no longer able to sustain life. But Nélaton and Campbell and Johnston and Beylard and Herbert by a consentaneous effort quickly inverted the body a third time, thus throwing all the blood possible to the brain, and again they began their efforts at artificial respiration. It seemed to me that she would never breathe again, but at last there was a spasmodic gasp, and after a long while there was another effort at inspiration, and after another long interval there was a third—they were far between; then we watched and waited, and wondered if there would be a fourth; at length it came, and more profoundly, and there was a long yawn, and the respiration became tolerably regular. Soon Dr. Beylard says, 'I feel the pulse again, but it is very weak.' Nélaton after some moments ejaculates, 'The color of the tongue and lips is more natural.' Campbell says, 'The vomiting is favorable; see, she moves her hands, she is pushing against me.' But I was by no means sure that these movements were not merely signs of the last death-struggle, and so I repressed myself. Presently Dr. Johnston said, 'See here, doctor; see how she kicks; she is coming round again;' and very soon they all said, 'She is safe at last.' I replied, 'For Heaven's sake, keep her safe! I beg you not to put her on the table again until she is conscious.' This was the first and only suggestion I made during all these anxious moments, and it was acted upon; for she was held in the vertical position until she, in a manner, recovered semi-consciousness, opened her eyes, looked wildly around, and asked what was the matter. She was then, and not till then, laid on the table, and all present felt quite as solemn and thankful as I did; and we all in turn grasped Nélaton's hand and thanked him for having saved the life of this lovely woman.

"In a few minutes more the operation was finished, but, of course, without chloroform. The sutures were quickly inserted and separately twisted, and the patient put to bed; and on the eighth day thereafter I had the happiness to remove the sutures in the presence of M. Nélaton and show him the success of the operation."

Notwithstanding its favorable result in this case, inversion is not by any means invariably successful, and many instances are on record in which that as well as all other remedial measures has signally failed to prevent a fatal issue.

Antidotal Power of Amyl Nitrite.—This drug has been found to produce physiological effects which, in at least one important particular, are directly antagonistic to those which result from chloroform narcosis. Under the full influence of the latter drug the arterioles of the brain, at first congested, are ultimately contracted, with resultant brain anæmia, while amyl nitrite produces dilatation of the arterioles through paresis of their walls, and thus diminishes the resistance which the contracted vessels offer to the inflow of the blood. As a consequence of the greater rapidity with which the blood-currents can move in the dilated capillaries the pulsations of the heart are correspondingly accelerated, less resistance being offered to the systolic movement. This, however, is not a true stimulation, because, while there is an increased frequency in the number of heart-beats, the pulse-rate in many instances being more than doubled, their force is decidedly diminished. The wide dilatation of the blood-vessels of the brain, which amounts to one-third of the original diameter, is the important gain secured by this drug; and it can readily be seen how much this condition favors the return of blood to the brain by gravity when inversion is practised, and how the renewed stimulus to the nervous centres of circulation and respiration arising from this return may again call into activity those functions even when they have been completely suspended. It is only indirectly, through this mechanism, that amyl nitrite can be said to act as a cardiac stimulant. Its effect upon the temperature is in large doses one of marked depression, a fall of from one to three degrees being not infrequent, and even lower temperatures have been recorded as the result of its toxic action. Indeed, the dose required to produce the most favorable results in chloroform narcosis is a very small one—five or six drops: if given in too large amounts the flushing of the face and turgescence of the cerebral capillaries, which are its primary effects, will be succeeded by pallor, contraction of the arterioles, and marked depression of the heart's action.

In cases in which animals, previously narcotized by chloroform, have died after large doses of amyl nitrite, it has been found that the heart has become paralyzed, and, together with the entire venous system, engorged with cyanotic blood. While no fatal cases have yet been reported from its use upon the human subject, and while, indeed, it has been found to be a much safer remedy than was at first supposed, still great caution should be observed in its administration, as many persons are dangerously affected by even minute quantities; while, on the other hand, others can inhale comparatively large amounts without other than the usual physiological effects. As with other remedies of its class, a certain degree of tolerance is established by use, and the drug is now frequently inhaled with considerable freedom by persons who carry it with them constantly to ward off the paroxysm of epilepsy or to deaden the pain of angina pectoris.

As an antidote for chloroform five or six drops are placed upon a napkin or other suitable fabric and held to the mouth and nostrils of the patient. A very convenient method of keeping the drug ready for immediate use is in hermetically-sealed thin glass shells or capsules, containing five drops each. In using, the shells are placed upon the napkin or folded piece of lint and broken by a blow of the hand; the contents, escaping, are then readily inhaled.

So many cases are now on record in which amyl nitrite has been of apparent benefit in cases of suspended animation that no one should fail to have it ready for use when undertaking the administration of chloroform for anæsthetic purposes. When this antidote fails and artificial respiration and faradization prove alike ineffective, tracheotomy should at once be performed for the purpose of insufflation.

Secondary Effects of Chloroform Narcosis.—Abnormal symptoms may occur or pathological changes be developed after anæsthesia produced by chloroform as well as after etherization. The possible secondary effects of the two agents are not essentially different, and their treatment is the same. The necessity for watching the condition of the patient and carefully sustaining his bodily temperature after recovery from anæsthesia need hardly be reiterated here. Owing to the more decidedly depressing effect of the drug, such watchfulness is even more obligatory after chloroform than after ether. When the latter agent has been used secondary bronchial and pulmonary affections are of decidedly more frequent occurrence than when chloroform has been employed. Even with this agent, however, such results are occasionally met with, and when they occur must be treated upon the same general principles as those already detailed in connection with the subject of sulphuric ether. This remark, too, holds good with reference to gastric irritability, hysteria, or other functional disturbances or abnormalities of nervous action.

The most critical case of secondary disturbance the writer has been called upon to treat occurred after narcosis produced chiefly by chloroform, a small amount of ether also having been used. In this case, after the operation (amputation of the arm following a gunshot wound) an almost complete collapse ensued: the respiration was shallow and hurried; the action of the heart weak and tumultuous, no distinct pulsation being perceptible at the wrist; the face was cadaveric, the pupils dilated, and the temperature much reduced, while a profound nausea and incessant retching defeated all attempts to administer nourishment or stimuli by the stomach. In this condition, with but little amelioration of the symptoms, the patient, a robust young man, remained for nearly twenty hours. During this time heat was constantly applied to the surface of the body and stimulant enemata occasionally administered. The gastric irritability was finally overcome by giving every hour one-fourth of a grain of calomel and one drop of creasote in a pill of breadcrumb, and at shorter intervals a teaspoonful of ice-cream frozen hard and swallowed without previous melting in the mouth, thus combining nutrition with the sedation produced by cold. Under this treatment the patient fully rallied. So complete had been the stasis of blood in the pulmonary tissues that the revival of the vital forces was followed by an attack of acute pneumonia.

The late Dr. Thomas Wood of Cincinnati observed a case[1] in which the very first inhalation of chloroform produced retching, followed by vomiting before the patient became insensible; the anæsthesia was maintained for half an hour, and on the return of consciousness the gastric trouble reappeared, and continued until the close of life on the sixth day.

Occasionally an arrest of the bile-secreting function of the liver follows chloroform narcosis. The most marked instance of this result which ever came under the observation of the writer was in a case in which chloroform had been administered on some three or four successive days to prevent pain in the dilatation of a stricture of the urethra. A very sharp attack of jaundice ensued, the whole cutaneous surface becoming highly colored with the pigmentary matter of the bile.

The Relative Merits of Ether and Chloroform.

Nearly four decades have now elapsed since the introduction of modern anæsthetic processes, and during almost that entire period the relative advantages of ether and chloroform have been the subject of controversy. Such large practical experience in the use of anæsthetics has now been gained, and the knowledge of their physiological effects is so much more extended and accurate than at an earlier period in their history, that reasonably definite conclusions have been reached. That the use of chloroform is attended with greater danger than the use of ether is no longer disputed. All that is now claimed is that with proper care the danger of a fatal issue from chloroform is very small, and that the advantages which it possesses over ether in the more agreeable character of its vapor and the superior speed and efficiency of its action more than counterbalance the slight risk which its use entails. The general tendency of professional sentiment, however, is in antagonism to this view, and in America at least the dangers of chloroform are regarded as too great to justify its use save in exceptional cases. This sentiment is based not only upon the records of relative mortality, which constitute the strongest argument against chloroform, but upon the results of careful physiological research. The sphygmographic tracings[2] on p. 130 show very clearly the difference in the depressing effect upon the pulse of ether and chloroform respectively (Fig. 13).

[1] *System of Surgery*, Gross, p. 554.

[2] From Agnew's *Surgery*, p. 290, vol. ii.

The peculiar toxic influence which chloroform exerts upon the heart has been frequently demonstrated, as in the experiments performed by the committee on the action of anæsthetics appointed in 1877 by the British Medical Association,[1] in which they found that the heart of a frog exposed to the vapor of chloroform "became rapidly weaker until it ceased beating;" while when exposed under similar conditions to the vapor of ether "it continued beating for a considerable time—in fact, as long as the experiment continued." Warm-blooded animals also were experimented upon, the trachea being opened and artificial respi-

FIG. 13.

WITH ETHER.

Normal Pulse.

Full Anæsthesia.

WITH CHLOROFORM.

Normal Pulse.

Full Anæsthesia.

ration being carried on by means of a double-acting pump. When chloroform vapor was passed into the lungs with air the committee state that the right ventricle almost immediately began to distend, the heart stopping with the right ventricle engorged with blood. In the case of rabbits the heart often came to a standstill within a minute of the introduction of chloroform into the lungs. "The contrast was most striking when ether was used instead of chloroform, the other steps in the experiment being the same. Ether may be given for an indefinite period without interfering with the heart. We kept up artificial respiration with ether in the circuit for an hour, not including twenty minutes occupied in producing anæsthesia, and at the end of that time the exposed heart was beating as vigorously as at first."

A later report of the same committee[2] states that "chloroform has an unexpected and apparently capricious effect on the heart's action, the pressure being reduced with great rapidity to almost *nil*, while the pulsations are greatly retarded or even stopped. The occurrence of these sudden and unlooked-for effects on the heart's action seems to be a source of serious danger to life—all the more that in two instances they occurred more than a minute after chloroform had ceased to be administered and after the recovery of blood-pressure. . . . .

"As regards comparative danger, the three anæsthetics may be

[1] "Preliminary Report," *British Medical Journal*, Jan. 4, 1879.
[2] *British Medical Journal*, Dec. 18, 1880.

arranged in the following order: chloroform, ethidene, ether; and the ease with which the vital functions can be restored may be conversely stated thus: The circulation is more easily re-established when its cessation is due to ether than to ethidene, and when the result of ethidene than when chloroform has been used. The advantages which chloroform possesses over ether, in being more agreeable to the patient and more rapid in its action, in the complete insensibility produced by it, and the absence of excitement or movements during the operation, are more than counterbalanced by its additional dangers."

A similar committee, appointed by the Boston Society for Medical Improvement, reported in 1861 as follows: "Proper precautions being taken, sulphuric ether will produce entire insensibility in all cases, and no anæsthetic requires so few precautions in its use.

"There is no recorded case of death known to the committee attributed to sulphuric ether which cannot be explained on some other ground equally plausible, or in which, if it were possible to repeat the experiment, insensibility could not have been produced and death avoided. This cannot be said of any other anæsthetic."

Dr. Snow,[1] who gave chloroform freely, said: "I believe that ether is altogether incapable of causing the sudden death by paralysis of the heart which has caused the accidents which have happened during the administration of chloroform. I have not been able to kill an animal in that manner with ether, even when I have made it boil and administered the vapor almost pure. The heart has continued to beat after the natural breathing has ceased, even when the vapor has been administered without air; and in all cases in which animals have been made to breathe air saturated with ether vapor at the ordinary temperatures of this country they have always recovered if they were withdrawn from the vapor before the breathing had ceased; if the animal made a gasping inspiration after its removal from the ether, it recovered."

The distinguished physiologist, Prof. J. C. Dalton, at a meeting of the New York Academy of Medicine, March 18, 1880, said: "The difference between the manner in which death is produced by chloroform and by ether when given to animals has in my experience been very striking—so much so that I long ago abandoned the habitual use of chloroform while experimenting, because it was so annoying to lose an animal just before the experiment was required and could not be postponed."

James Sawyer, M. D., London, says: "The danger of chloroform lies in its lethal power as a cardiac depressant. . . . . Sooner or later chloroform must give way to ether as a surgical anæsthetic, just as ether must drop out of use whenever another anæsthetic as efficient in annihilating pain, but safer to life, shall appear."

Dr. Thomas Jones, who had been for eleven years administrator of anæsthetics in St. George's Hospital, London, wrote in 1872 as follows: "I have administered chloroform in more than six thousand cases. . . . . I confess experience has taught me that chloroform, even when most carefully administered, is more dangerous than is generally supposed.

[1] *Anæsthetics*, 1858, p. 362.

If I was unfortunately compelled to take an anæsthetic, nothing could induce me to take chloroform."[1]

Mr. Jonathan Hutchinson, in a communication to the *British Medical Journal*,[2] says:

"I have been familiar with anæsthetics from the date of their introduction, and have taken great interest in the prevention of mortality from their use. Many years ago, when my duties in connection with the *Medical Times and Gazette* required my daily attendance in the operating theatres of the various hospitals, I was the witness of more deaths from chloroform than have probably fallen under the observation of any one else. Since then I have habitually read all reports of deaths from anæsthetics, and during a long period have also had very large opportunities, both in hospital and in private practice, for judging of the comparative merits of the different ones in use, and also of different modes of administration. The result has been the formation of an opinion so strongly in favor of ether that I should consider myself very culpable if I ever permitted the use of chloroform except in certain cases. The exceptions are the old and the very young: under six months and over sixty years chloroform is, I think, preferable. At all other ages, regardless of states of health, I employ ether. . . . . I have personally lost but one patient (a chloroform case), nearly twenty years ago, but many times have I been alarmed for my patient's safety, and not unfrequently obliged to practise artificial respiration long before signs of returning animation were produced. Now, with ether these cases do not occur. . . . . If only complicated instruments be avoided, and if nothing but the sponge and towel be used, I believe there is absolutely no danger. . . . . It is to the employment of inhalers, which obstruct respiration, I believe, that the occasional ill effects of ether inhalation are due.

"My reason for making the rule as regards age is this: With aged persons ether often disagrees, leaving headache or tendency to stupor for many hours afterward. Chloroform, on the contrary, agrees well with the old, and appears in them to be almost free from risks. The same freedom from danger appears to exist in early infancy."

Prof. J. Morgan, M. D., F. R. C. S., says:[3]

"I have used ether in several cases in which I had used chloroform previously, and found that the struggling and spasmodic stage, which was energetic and almost uncontrollable in chloroformization, was *nil* with ether; . . . . the experience of others confirms this statement. . . . . Sickness of stomach is said to succeed to etherization more than to the use of chloroform: my experience with both leads me altogether to disagree."

The late Prof. Gross, in reply to a letter of inquiry, wrote:

"I have employed anæsthetics ever since their introduction. For many years I employed nothing but chloroform in its pure state, and have never met with a fatal accident, although on several occasions symptoms of a very alarming character arose, and that even when the greatest possible care in its administration was observed. During the last few years I have used ether more frequently than chloroform—first, because it is *unquestionably* a safer agent; second, because I have become more timid in regard to other anæs-

[1] *National Dispensatory*, Stillé and Maisch, p. 407.

[2] Nov. 6, 1880.

[3] *Dublin Journal of Medical Science*, vol. liv., 1872, pp. 360–368.

thetics; and lastly, because professional and public sentiment is decidedly arrayed against chloroform."[1]

These citations might be almost indefinitely extended in evidence of the fact that ether is rapidly supplanting chloroform in the confidence of the medical profession throughout the world. Its use in the hospitals of this country is now almost universal, while, according to a paper read by Dr. Jones before the Cork Med.-Chir. Association, "ether is now used exclusively in at least one-third of the hospitals of Great Britain, and a mixture of ether and chloroform in nearly another third, while there is shown a general disposition of the profession throughout the United Kingdom to abandon the one for the other."[2]

Dr. J. C. Reeve, being desirous of obtaining information as to the relative use of chloroform and ether, and other facts relating to their employment in this country, addressed a circular to the leading surgeons throughout the United States. The following statements, made by Dr. Reeve,[3] are based upon the information thus obtained:

"Some strongly-marked geographical lines can be drawn in this country in regard to the use of the two anæsthetics.

"Thus in all New England, of fourteen surgeons, not one uses anything but ether.

"Taking next the cities of New York, Brooklyn, and Philadelphia, containing together about two and a half millions of inhabitants, and which may be classed together from their proximity and similar metropolitan character, in these cities there are thirty-six surgeons who use ether or chloroform indifferently, and only two who declare that they use only chloroform.

"The remainder of the country may be divided into two sections, North and South, by a line running on the boundary between Maryland and Pennsylvania, along the Ohio River, and thence directly west. These sections present a striking contrast as to the use of anæsthetics. In the North thirty-seven surgeons use ether, twelve use chloroform, and seven either indifferently; four use a mixture of the two; two, the mixture of alcohol one part, chloroform two parts, ether three parts; one, a mixture of one part chloroform to three parts ether; and one, a mixture of one to two.

"In the Southern section of the country twenty surgeons use chloroform and twelve ether. One uses the mixture of one to three, and two use the alcohol-chloroform-ether mixture frequently when ether fails.

"In regard to abandoning the use of chloroform for ether, taking the whole country together, forty surgeons, or about 30 per cent., have made the change within ten years, and nine more within about fifteen years. Five have changed from ether to chloroform, giving as a reason the superior practical advantages of the latter. In the majority of cases the reason given for changing from chloroform to ether is death or dangerous symptoms observed in patients under chloroform. Quite a respectable percentage, however, give only the 'influence of professional opinion' as the determining cause.

"One hundred and forty-four surgeons report that they have seen thirty-four deaths from chloroform and eight from ether, one of the latter having been from obstinate vomiting afterward.

[1] Holmes's *System of Surgery*, p. 550. [2] *Ibid.*, p. 549.
[3] *Ibid.*, "Anæsthetics," p. 550.

"Dangerous symptoms from chloroform are reported as having been witnessed two hundred and thirty-one times. . . . . Dangerous symptoms from ether are reported as witnessed fifty-six times."

Prof. Lyman in his work on *Artificial Anæsthesia and Anæsthetics* (pp. 136–196) gives the details of three hundred and twenty-five cases of sudden death from chloroform, and says: "A perusal of the history of these cases is sufficient to produce the conviction that comparatively few of the cases of death from chloroform have been acknowledged and published. The vast majority of the cases thus far reported have occurred in the hospitals of Great Britain. A death from the use of chloroform in private practice is seldom announced, unless it may chance to have happened in the office of an unlucky dentist. Then, of course, there is great publicity and the event is carefully chronicled. Occasionally some elderly physician alludes in a cautious manner to a case of which he was cognizant long years ago in a remote quarter of the earth. In some such way it has been published[1] that in Cincinnati and its adjacent territory not less than twenty-five deaths from chloroform had occurred since the introduction of that anæsthetic."

Prof. Bartholow[2] states that the reported deaths from chloroform now (1879) amount in the aggregate to about five hundred.

Dr. Laurence Turnbull[3] gives three hundred and seventy as the total of reported and fully authenticated cases of death from chloroform which he had been able to obtain up to the year 1879.

Chloroform in Obstetrical Practice and for Young Children.—Many of those who deprecate the use of chloroform for other classes of cases claim that young children and women in the throes of labor possess a special immunity from danger in chloroform narcosis. So far as children are concerned, the only reasonable explanation of such immunity is that suggested by Dr. Reeve,[4] that chloroform is more carefully administered than when it is employed upon adults. Evidence that while intrinsically unsafe for adults it is intrinsically safe for young children is not forthcoming, and can hardly be assumed as a postulate to any known principle of physiological law. It is certain that children succumb far more readily to the toxic influences of all other narcotics than do adults, and it is difficult to believe that the rule should not hold good with chloroform. Indeed, that children have died under chloroform is a matter of record.[5]

The testimony as to the almost absolute safety with which it can be given to parturient women is very strong. According to the committee of the Royal Medical and Chirurgical Society there is no well-authenticated instance of sudden death recorded, either in this country or abroad, as occurring from the administration of anæsthetics during natural labor when such administration has been conducted by a qualified medical man.

Prof. Bartholow[6] says that "chloroform is to be preferred in labor, because more pleasant to inhale, more prompt in action, and without inflammability. The consideration of safety must necessarily take

[1] *The Clinic*, p. 150, March 31, 1877. [2] *Materia Medica and Therapeutics*, p. 367.
[3] *Anæsthetic Manual*, p. 113. [4] *American Journ. Med. Sciences*, Jan., 1867, p. 182.
[5] *Anæsthesia, loc. cit.*, p. 166. [6] *Materia Medica and Therapeutics*, p. 367.

precedence, but experience has shown that chloroform is perfectly safe in labor when properly administered."

Various theories have been presented in explanation of the greater safety of chloroform in this class of cases. By some it is claimed that the extreme pain incident to labor increases the resistance which the vital forces offer to the toxic influences of the drug. This increased resistance, however, is not apparent in the earlier stages of anæsthesia, women in labor yielding quite as readily to the anæsthetic as those who are non-parturient, and, as pain is thus found not to retard the primary influence of the agent, there is no good reason for the assumption that it would modify favorably its extreme toxic effects. Indeed, such a theory is in direct antagonism to the universally-recognized fact, so frequently illustrated in obstetrical practice, that extreme pain powerfully depresses all the vital energies, and when too prolonged causes death from exhaustion.

A more plausible theory is that the "physiological congestion of the brain produced by straining in labor antagonizes the cerebral anæmia which is the physiological effect of chloroform." Prof. Lyman considers this questionable, and says: [1]

"The greater immunity of these patients is probably due to the fact that they are selected patients, as it were. Young women in the prime of life, at an epoch when all the nutritive functions of the body are at their highest degree of activity, must necessarily present the best possible cases for tolerance of anæsthesia. Such patients are in a very different condition from that in which we find the victim of disease or of shock upon whom the surgeon is called to operate."

This theory would seem to find confirmation in the similar exemption from danger which has attended the use of chloroform in military surgery. Soldiers, to a far higher extent than parturient women, are a selected class, usually in the prime of life, and the recorded cases of death from chloroform among them are very few in number. Dr. Hunter McGuire of Richmond, Va., states that in the division of the Confederate Army to which he was attached it was administered twenty-eight thousand times without a death;" [2] and reports almost equally favorable have been given concerning its use in the more recent wars of continental Europe.

It does not fall within the scope of this paper to discuss the details of anæsthetic practice in those departments of medicine foreign to dentistry. The question as to the value of anæsthetics in obstetrics and gynæcology, or as to the normal or pathological conditions which render their employment permissible or imperative, will not be considered. The writer, however, fully agrees with the conclusion of Prof. Lyman,[3] that the true use of chloroform in obstetrical practice is as an anodyne, and that "when complete anæsthesia is required for the graver operations of midwifery, sulphuric ether should be preferred to all other articles."

CHLOROFORM IN DENTISTRY.—Whatever the other fields of medicine in which chloroform may safely be employed, there are now but few who

[1] *Artificial Anæsthesia and Anæsthetics*, p. 72. [2] Holmes's *System of Surgery*, p. 551.
[3] *Op. cit.*, p. 69.

dissent from the opinion that its special dangers absolutely inhibit its use in dentistry: the large mortality which has attended its employment in operations upon the teeth sufficiently attest the justice of this conclusion. In the three hundred and twenty-five cases of death from chloroform collected by Prof. Lyman there were thirty-five which occurred during or after its administration for the extraction of the teeth, this being more than for any single operation except the "removal of tumors, including cancerous breasts and tongues," during which operations also thirty-five deaths took place. Dr. Turnbull reports during the decades from 1869 to 1879 twelve cases of death from chloroform given for extraction of the teeth, one from chloroform given for toothache, one where given for asthma and toothache, and one in which the operation was for epithelioma of the tongue. This list, large as it is, would doubtless have been vastly augmented had not the widespread introduction of nitrous oxide gas as an anæsthetic, which took place during and immediately preceding that period, generally displaced from use in dentistry the more dangerous anæsthetics. Even now, however, cases are occasionally reported.

Deaths from Chloroform in Dental Practice.—Thus, quite recently Mrs. Dr. E. M. Watts, the wife of a physician of Portsmouth, Va., fell a victim to the drug, although her own husband was the administrator. According to the report in a local paper, she had taken the drug on three previous occasions without any bad effect, but always against the earnest remonstrances of her husband. She was in a reclining chair. The quantity inhaled was about two drachms on an open sponge. Teeth extracted ten, and three roots. Time from commencement of inhalation to end of extracting teeth, not over five minutes. Chloroform administered by Dr. Watt, teeth extracted by Dr. John Linn.

Still more recently (Feb. 7, 1884) a very similar case is reported in the Scranton (Pa.) *Republican*, the victim being Mrs. James Stevenson, a lady thirty-six years old and the mother of seven children. She was accompanied to the dental office of Dr. W. H. Heist by her physician, Dr. A. Strang, who "examined her very carefully as to the condition of her heart and lungs, and found her a proper subject for the administration of the soporific." Sixteen teeth were to be removed because of a neuralgic affection attributed to their decayed condition and from a desire for an artificial denture. Ether and chloroform were given (proportions not stated) by Dr. Strang, and the teeth extracted by Dr. Heist. The report gives the result as follows:

"The physician noted the condition of the pulsation and respiration carefully during the operation. In two minutes after the first inhalation two teeth were taken out, and the lady revived, rose to a sitting posture, spit out the blood, and lay back again. More of the chloroform and ether was given, and then nine teeth were removed, after which she again revived, spit, rested, and asked if the teeth were not all out. The anæsthetic was again applied, and five more teeth were taken out, completing the work of extracting. About two minutes after the last tooth was taken out she threw her head violently back, rolled up her eyes, and apparently fainted away. All the remedies usual in cases of swooning were resorted to. Cold water was dashed in her face, artificial respiration was performed, then hypodermic injections of brandy were made, without any response whatever in the way of revival. Another physician was called in, and arrived in ten minutes after she had fainted. Her pulse was then beating faintly, but no effort could restore her to animation.

"The post-mortem," says the report, "revealed the lungs in a condition of collapse and somewhat congested, proving that breathing stopped before the heart ceased to pulsate. The right side of the heart was dilated and had thin, weak walls. There was no valvular disease of the heart. On the top of the heart was found a small cystic tumor that seemed to press upon the artery—the coronal artery—that supplies the heart with nourishment. This tumor, by pressing upon an important nerve, might have been a considerable factor in causing her death. The stomach showed a catarrhal condition and gastritis was indicated."

The details given concerning the first of these cases are too meagre to afford a basis for judgment as to the influence which the mode in which the anæsthetic was administered may have exerted in producing the fatal result. Without presuming, as details are not given, to sit in judgment upon the operative procedure in either of these specific cases, the writer would remark that, as a general principle, the conditions which render necessary the sacrifice of so large a number of teeth at any one time in the history of a human life ought to be, in the present state of dental science, exceptional: malignant disease of the jaws or alveoli sometimes demands such a sacrifice, and there are incurable pathological conditions of the teeth themselves which sometimes, though rarely, make the extraction of a considerable number imperative; but it has never occurred in the experience of the writer that the ravages of simple caries or the existence of lesions directly or indirectly dependent upon caries have wrought such havoc in a human denture that something far better for the patient, even if neuralgic, could not be accomplished than the extraction of one-half the normal dental equipment. In a vast majority of cases of true neuralgia such wholesale edentation is utterly futile, the last state of the patient being worse than the first.

Assuming that the extraction of so large a number of teeth at a sitting becomes necessary, chloroform is, certainly, not the agent which should be employed as the anæsthetic.

Reasons for Fatality in Dental Practice.—The fact has already been emphasized in connection with the subject of sulphuric ether (see pp. 84–87) that, owing to the close contiguity of, if not direct commissural connection between, the nucleus of the fifth nerve and the nucleus of the pneumogastric, as well as to their intimate reflex relations, the region supplied by the fifth is one of special danger when operated upon under the influence of anæsthetics. If the patient be imperfectly anæsthetized, the shock produced by the extraction of a single tooth may so stimulate the inhibitory function of the pneumogastric as to produce complete arrest of the cardiac movements: how much more likely is this be the result when many teeth are extracted, and when the heart itself is weakened by the specifically depressant influence of chloroform! Beyond all question it is to this combination of influences that the great mortality from chloroform narcosis in dentistry is directly due. It is very evident that in the second of the cases just quoted anæsthesia was at no time sufficiently profound. Even with chloroform, much less with chloroform and ether, anæsthesia cannot, in an adult, be safely effected in two minutes, which was the time allowed before the extraction of the first two teeth: the quick revival, sitting up, spitting out of blood, and lying back again, repeated after each series of extractions, all indicate that anodyne and not full anæsthetic doses were administered.

The coroner's jury found that the deceased came to her death "from a fainting fit caused by excitement and shock incident to the extraction of a number of teeth, and that there was sufficient disease of the heart—though not readily recognizable during life—to cause death by any unusual excitement;" but had a profound anæsthesia been effected by such an agent as sulphuric ether, used alone, the heart would not have been specifically assailed, shock would not have been received or transmitted, excitement would have been calmed. That the influence of the anæsthetic is a potent factor in the mechanism of death under such conditions is fully demonstrated by the relatively small mortality which has attended similar dental operations under ether, and by an almost absolute immunity from a fatal result which has followed even the most wholesale extractions under nitrous oxide gas. Clearly, in dental practice shock or excitement, alone or combined, very rarely kills, for both conditions are as likely to be incident to operations under nitrous oxide gas as under other agents: it is the drug which kills.

That chloroform, as well as other anæsthetics, is often ignorantly given by incompetent persons, and that many cases of fatality are attributable to this cause rather than to inherent vices in the agent itself, is unquestionable. Case after case might be quoted in which every condition necessary to the safe induction of the anæsthetic state with either ether or chloroform has been systematically violated; and in a great measure the responsibility for such a state of things must rest upon the lax public sentiment which until quite a recent period has made it possible for even the most ignorant and incompetent to practise either medicine or dentistry in any State in the Union. No small share of the blame, however, must attach to the schools of instruction. The subject of anæsthesia and anæsthetics has too often been treated as a matter of trivial importance, to be dismissed in a single lecture or less. Even now there are not many medical or dental colleges in which full and detailed instruction in the physiological and pathological relations of artificial anæsthesia is given, and practical drill enforced both in the details of the administration of anæsthetic agents and the institution of resuscitative measures when such are required.

Ethyl Bromide.

This substance (C_2H_5Br), otherwise known as bromide of ethyl or hydrobromic ether, has been used to so considerable an extent in dental practice, and by some practitioners is still so highly recommended, that a brief account of its properties and effects would seem to be demanded.

Discovery and Early Use.—It was discovered in the year 1827 by Serulas. In 1849, Dr. Thomas Nunnelly of Leeds used it in experiments upon animals, anæsthetic effects being produced in several instances. Owing to the costliness of the drug these researches were abandoned for the time. Dr. Nunnelly subsequently employed it as an anæsthetic upon the human subject, and in a paper read before the British Medical Association in 1865 stated that he had given it as an anæsthetic "in all the principal operations at the Leeds General Eye and Ear Infirmary." Dr. Richardson of London, too, strongly recommended it. Babuteau of Paris in the year 1876 experimented with it both upon animals and plants: the latter he found to die in two hours after exposure to an atmosphere saturated with the vapor of the drug. In 1878, Dr. Laurence Turnbull of Philadelphia gave it repeatedly for the relief of tinnitus aurium and other affections of the ears, and also as an anæsthetic in minor surgical operations, he being the first to use the agent in this country. Dr. R. J. Levis soon introduced it into his surgical practice, and in April, 1879, it was used by him in the Pennsylvania Hospital. Since that period it has been used for anæsthetic purposes in hundreds of cases, both in this country and in Europe.

Preparation and Properties.—Ethyl bromide is prepared by distilling together absolute alcohol and bromine in the presence of amorphous phosphorus. The following equation represents the reaction:

$$\underset{\text{Bromine.}}{5Br_2} + \underset{\text{Phosphorus.}}{P_2} + \underset{\text{Alcohol.}}{10C_2H_6O} = \underset{\text{Ethyl bromide.}}{10C_2H_5Br} + \underset{\text{Phosphoric acid.}}{2H_3PO_4} + \underset{\text{Water.}}{2H_2O.}$$

It is a colorless, transparent liquid, having a characteristic ethereal odor and a warm, sweetish taste, disagreeable in character. In water it is but slightly soluble, but alcohol and ether combine with it in all proportions. The density of the fluid at 59° F. is 1.419; vapor density, 3.754; boiling-point, 105.2° F. When ignited, which is not readily accomplished, it burns with a greenish flame free from smoke.

Great difficulty is found in obtaining ethyl bromide in an absolutely pure state, and the utmost care in its preparation is required. Owing to the instability of the compound, secondary decompositions may occur either during or after its distillation, the impurities thus formed being often highly deleterious.

Effects of Ethyl Bromide.—As it seems quite certain that this agent will never come into general use, a full analysis of its physiological effects is not deemed necessary in this place. They differ only in minor particulars from those already detailed in connection with the study of ether and chloroform. Like the latter agent, it has been found to greatly depress the circulation, diminishing both the force and frequency of the movements of the heart. According to Dr. Ott, it kills by paralysis of the respiratory centres, to which paralysis the cardiac depression is tributary.

The advantages claimed for the agent are that it is much more rapid in its action than chloroform, and produces less muscular excitement; that the vapor when inhaled in the proportions of from 8 to 10 per cent. produces little bronchial irritation, and that vomiting is of infrequent occurrence; while a rapid elimination from the system through the lungs and kidneys ensures a speedy and full recovery. Dr. Roberts[1] says: "The effect is transient: in a few seconds after removing the towel the patient is able to talk intelligently, and in a minute or two he can leave the operating-table and walk away with scarcely a stagger. This circumstance is doubtless an element of safety, but is undesirable at times, because when necessary to remove the towel the patient almost instantly recovers sensibility. . . . . The amount consumed varies, of course, with the time the anæsthesia is maintained; usually one or two fluidrachms are poured upon the towel and repeated as demanded."

Fatal Cases.—Notwithstanding the claims in its favor, several deaths have occurred from its use, and but few now continue its advocacy. One death occurred May 26, 1880, in Jefferson Hospital, Philadelphia, the patient being a young man much debilitated by disease of the kidneys and stone in the bladder, the operation being for the removal of the calculus. Before the administration of the anæsthetic fifteen grains of quinine and "a stimulant" were given. About three fluidrachms of the anæsthetic were required to produce full anæsthesia, but immediately after the commencement of the operation respiration suddenly ceased, and all efforts at resuscitation—artificial respiration, amyl nitrite, the electric current, etc.—proved abortive. As the autopsy showed, the case was complicated not only by disease of the urinary tract, but also by serious lesions in the lung-tissue.

Another case occurred in the practice of Dr. J. Marion Sims. The details are given in a paper read by him before the New York Academy of Medicine March 18, 1880. The operation required was the removal of an enlarged ovary. At the end of ten minutes after beginning the inhalation of the anæsthetic the patient, a Miss B——, "could be kept quiet. Pulse 86, full and strong; respiration soft and regular, but above regular standard. During first twenty minutes had used two ounces of the hydrobromic ether. At that time she vomited the contents of the stomach. At the end of forty minutes she vomited again with some straining." The operation lasted one and a half hours. Her condition was good during the whole time. No unusual dilatation of the pupils. In all, about four and a half or five ounces of ethyl bromide were used. She recovered quickly from the anæsthetic after being put to bed, but had "the most distressing vomiting imaginable." This continued uninterruptedly, accompanied by free movements of the bowels —thin, yellowish, watery, very offensive, having so strong a smell of ethyl bromide as to attract the attention of the inmates of the house: five movements occurred in three hours. The pulse and respiration became very rapid, and the pulse finally imperceptible. The patient died in twenty-one hours after the operation. Severe convulsions occurred just before death, with "frantic ravings and heartrending screams."

At the post-mortem all parts of the body seemed saturated with ethyl bromide. When the kidneys were laid open and brought near the nose, "it was almost like smelling ether from an open bottle." The kidneys were healthy, but only five ounces and one drachm of

[1] Bryant's *Surgery*, p. 959.

urine were passed after the operation, and catheterization a few hours before death produced no urine. There was no peritonitis.

In commenting upon the case Dr. Sims remarks:

"In this case the kidneys were locked up, as it were, and hence the bowels were called on to aid the lungs in getting rid of the poison. It is altogether probable that the cholerine was due wholly to the action of ethyl bromide. If the operation had been comparatively short, if it had lasted only twenty or thirty minutes, if it had terminated before my patient's system, solids as well as fluids, became thoroughly saturated with it,—she would in all probability have recovered; but as it was it seemed to kill by supersaturation which could not be eliminated, even with the aid of the whole mucous tract of the alimentary canal to aid the lungs. . . . . The inference I draw from the facts in the history of the case is that the anæsthetic was the cause of death, while the manner of death may have been by uræmic poisoning. The lesson from this is never to give bromide of ethyl in prolonged operations, and never to give it where there is organic disease of the kidneys."

Nature of Toxic Influence.—Much of the favor with which the suggestion of the use of ethyl bromide was received was based upon a vague and mistaken assumption that because the less volatile but more permanent combinations of bromine, as in potassium bromide, etc., could be taken internally in large doses with only mildly sedative effects, therefore when it simply took the place of oxygen in the ethyl radical it must prove equally innocuous. Of course nothing could be more mistaken than this line of reasoning, because bromine uncombined is a highly irritant poison, and its connection with the ethyl molecule is so unstable that, as already indicated, its decomposition is most easily effected, and possibly is effected in the circulation, whereas the bromides of potassium, sodium, etc. are stable salts, which enter the system and are eliminated from the system as such, the toxic influence—both physiological and chemical, if there be a distinction—of the bromine being to a great extent masked by its molecular union with the bases with which it has entered into combination.

But without assuming that such a decomposition usually occurs, it is now a well-established principle that the presence of any toxic substance in an anæsthetic, however firmly it may be held in combination by its atomic affinities, is a source of danger. In other words, those anæsthetics are safest whose elements in themselves are harmless. Thus, taking the structure of sulphuric ether, $2(C_2H_5)O$, we have in carbon an agent which is altogether inert except in combination, and in hydrogen and oxygen two gases, either of which, under proper conditions, may be breathed with entire impunity, and one of which is necessary to life. The nitrogen, which is the element in combination with oxygen in nitrous oxide gas, N_2O, is also, when uncombined, an inert substance, which when breathed acts only as a diluent of the oxygen of the air. Thus, these two agents, being built of elements so little inimical to man's safety, are demonstrated to best conserve that safety in practical anæsthesia.

It is true that carbon, hydrogen, oxygen, and nitrogen, although singly thus harmless, are capable of entering into combinations, as in the poisonous alkaloids, possessing the most deadly potencies; and such potencies, indeed, if not restrained, they possess in the ether and nitrous-oxide combinations; but the practical result still remains that under proper restraint they have proved less harmful than all other agents of their class, and that the combination of an atom of bromine instead of an atom of oxygen with the ethyl radical increases the dangers of anæsthesia.

This is also true of all chlorine combinations with either methyl or ethyl radicles, such as chloroform, $CHCl_3$, or ethidene, $C_2H_4Cl_2$. The latter agent the anæsthetic committee of the British Medical Association found to be safer than chloroform, but less safe than ether. Its superiority over the former agent is easily explained by the fact that it contains so much less chlorine proportionately to the other elements which enter into its composition, while the superiority of ether is equally attributable to the entire absence of chlorine and all other toxic elements from its molecule.

Methyl Iodide.—This view of the active part which bromine and chlorine play in the toxic effects produced by those anæsthetics into which they respectively enter finds further confirmation in the poisonous effects produced by methyl iodide, CH_3I, which, being volatile, has also been experimented with for anæsthetic purposes. As bromine, chlorine, and iodine are nearly identical in their leading chemical affinities, so are they closely allied in their physiological effects. Methyl iodide, like ethyl bromide, is easily decomposed, either in the respiratory tract or in the circulation, the specific influences of the drug being manifested by the usual irritant effects upon the broncho-pulmonary mucous membrane, resulting in cough, increased mucous secretion, and frequently in spasm of the glottis. Concerning this agent Sir James Y. Simpson[1] says: "I found it very powerfully anæsthetic, but dangerously so. After inhaling a very small quantity for two or three minutes I remained for some seconds without feeling much effect, but objects immediately began to multiply before my eyes, and I fell down in a state of insensibility, which continued for upward of an hour. I did not completely recover from the effects of it for some days."

The greater violence of the chlorine, bromine, and iodine derivatives is by Professor Leffmann thought to be due in part to the difficulty of oxidation of these elements; ether, alcohol, and bodies of that class being with some ease converted into carbon dioxide and water, while the halogens are not so convertible. Be the cause what it may, enough has been said to show conclusively that the volatile compounds of chlorine, bromine, and iodine are, when inhaled, alike dangerous, although not equally so. It seems probable that the chlorine compounds are the least harmful of the three; but whatever may be the contingencies making necessary their employment in other departments of the healing art, they certainly have no place in the practice of dental surgery.

Anæsthetic Combinations.—Admitting that the volatile chlorine, bromine, and iodine compounds are specifically poisonous, the objections to their use as anæsthetics are not materially modified by giving them

[1] *Anæsthesia,* p. 262.

in combination with less dangerous agents, such as sulphuric ether and alcohol. Numerous formulæ for these combinations have been given to the world backed by the highest commendations of their inventors; but while, on general principles, it may be assumed that the less of a dangerous anæsthetic inhaled the better, and therefore that the substitution of ether for chloroform in any proportion is an advantage, still the effects of chloroform are so erratic, and the quantity required to produce fatal results has sometimes been so small, that, practically, the dangers of anæsthesia are hardly diminished by such combinations. It is not found that the specific influence of chloroform is materially modified because ether is being inhaled at the same time; indeed, it would be modified only in degree even if there were a chemical union, instead of an imperfect mechanical admixture, of the two vapors; for it must be remembered that each fluid has its own point and rate of vaporization, and that they therefore do not by any means pass into the respiratory tract in the same proportions as those in which they were commingled in the liquid form. This was long ago shown by Dr. Snow, who said: "Some practitioners have recommended the inhalation of the vapor from a mixture of chloroform and ether, but the result is a combination of the undesirable qualities of both agents, without any compensating advantage. Ether is about six times as volatile as chloroform; that is to say, if equal measures of each be placed in two evaporating dishes kept side by side at the same temperature, the ether evaporates in about one-sixth the time of the chloroform; and when the two liquids are mixed, although they then evaporate together, the ether is converted into vapor much more rapidly; and in whatever proportions they are combined, before the whole is evaporated the last portion of the liquid is nearly all chloroform : the consequence is that at the commencement of the inhalation the vapor inspired is chiefly ether, and toward the end nearly all chloroform, the patient experiencing the stronger pungency of the ether when it is most objectionable, and inhaling the more powerful vapor at the conclusion, when there is most need to proceed cautiously."[1]

Combinations with Alcohol.—Owing to the stimulating effect of its vapor a combination of alcohol with chloroform or with chloroform and ether is much favored by many operators. The following formula, known as the "A. C. E. mixture," was among others recommended by the chloroform committee of the London Medico-Chirurgical Society:

Alcohol,	1 part;
Chloroform,	2 parts;
Ether,	3 parts.

Dr. Sansom states that he has found the alcohol vapor to sustain the action of the heart during the influence of chloroform, and recommends a combination of equal parts of chloroform and absolute alcohol as "an excellent anæsthetic, which gives off a proportion of chloroform vapor in a given time exactly half of that which is given off by chloroform pure and simple."

As shown by Snow, and as has since then been repeatedly demonstrated, all these mixtures are merely mechanical, and their constituents

[1] *Anæsthetics*, pp. 369, 370.

evaporate in the order of their volatility—ether first, chloroform next, and alcohol, if present, last of all, so that at no stage in the administration of such mixtures can the operator be sure of the exact nature of the vapor inhaled.

NITROUS OXIDE.

Nitrous oxide (N_2O) is a colorless gas having a faint odor and sweetish taste. Its specific gravity, compared to air, is about 1.6. By a pressure of fifty atmospheres at a temperature of 40° F. it may be condensed into a liquid form, and in this state, when confined in vessels of sufficient strength and impermeability, may be kept for an indefinite period. Although volatilizing with great rapidity when released from pressure, the liquefied gas may, with proper precautions, be drawn into test-tubes or other receptacles for examination. It is a colorless fluid, having a specific gravity of 0.908. At a very low temperature (— 148° F.) it congeals into a transparent crystalline solid. When liquid nitrous oxide and carbon disulphide are mixed and evaporated *in vacuo* a temperature of — 220° F. may be obtained. So rapid is the volatilization of the liquefied gas that when mixed with water and allowed to volatilize in air the water will be frozen.

At high temperatures nitrous oxide supports combustion almost as effectively as pure oxygen, and all combustibles, when once ignited, continue to burn in it with great brilliancy. Thus the incandescent wick of a newly-extinguished taper, if placed in a receiver containing the gas, will be kindled into flame, as also will slowly-burning charcoal, sulphur, or phosphorus. This effect, however, is due to the decomposition of the nitrous oxide molecule effected by contact with the ignited object: oxygen, being thus set free from its chemical union with nitrogen, is in a condition to satisfy its chemical affinities by entering into new combinations with the elements of the combustible, just as when it is presented merely mechanically mixed with nitrogen in atmospheric air.

Nitrous oxide is to a limited extent soluble in water. At ordinary temperatures water absorbs about 80 per cent. by volume of it (Dalton). The warmer the water the less gas is dissolved or retained in solution. According to Bunsen,[1] one volume of water at a temperature of 0° C. (32° F.) and $0^m.76$ barometric pressure dissolves 1.3052 volumes of the gas; at 8° C. (46.4° F.), 0.9858 of a volume; and at 23° C. (73.4° F.), only 0.6216 of a volume.

Preparation.—Nitrous oxide is usually obtained by the decomposition of ammonium nitrate (NH_4NO_3), which when heated to a temperature of about 392° F. yields water and nitrous oxide gas ($NH_4NO_3 = 2H_2O + N_2O$). The ammonium nitrate itself is prepared by acting upon ammonia or its carbonate with nitric acid diluted with an equal volume of water. After all chemical action has ceased the solution is evaporated to the point of solidification. A crystalline mass remains which is broken up into fragments of convenient size and sent into commerce. The salt crystallizes in rhombic prisms. By processes known to the manufacturers it may be obtained in a granulated condi-

[1] *Gasometry.*

tion; which form is, owing to the relatively small size of the granules, convenient for introduction into the retort.

The crystals obtained by the simple cooling of a hot saturated solution of the salt contain a large amount of water of crystallization $NH_4NO_3 12H_2O$ (Attfield), but by exposing the crystals to the temperature of 310° F. the water is driven off and the anhydrous salt (NH_4NO_3) remains. This, however, has some affinity for water, and deliquesces upon the surface when exposed to moist air: half its weight of water will dissolve it completely. In dissolving a very considerable reduction of temperature takes place. As upon the absolute purity of the ammonium nitrate depends the purity of the gas prepared from it, the salt should be carefully tested before using.

Tests for Purity of Ammonium Nitrate.

General Test.—A pure specimen slowly heated in a test-tube or upon platinum-foil will be completely volatilized, leaving no residue.

Test for Acids or Alkalies.—A strong solution of pure ammonium nitrate in distilled water should not give either an acid or alkaline reaction, but should be neutral. Hence the color of either red or blue litmus-paper dipped in such a solution should remain unchanged.

Test for Chlorides.—Any chlorides present may be detected by placing in an aqueous solution of the ammonium nitrate a few drops of nitric acid—to prevent carbonates, phosphates, or free ammonia, should such substances also contaminate the specimen, from interfering with the test—and then adding a solution of silver nitrate: silver chloride will appear as a white precipitate.

Test for Sulphates.—The presence of sulphates may be determined by adding to the solution of ammonium nitrate, acidulated with nitric acid as in the test given for chlorides, barium chloride, which, with a sulphate, will form a white precipitate of barium sulphate.

These tests are not by any means superfluous, even when the salt has been obtained from known and reliable sources, as, assuming that it has been properly made, there is always the possibility of subsequent contamination through the absorption of deleterious vapors, such absorption being favored by its deliquescent properties. An instance of this kind occurred some years ago in the laboratory of a leading manufacturing chemist in this city, where by accidental exposure to chlorine fumes a considerable quantity of that gas was absorbed by the ammonium nitrate in stock, attention being first called to the fact by the unpleasant effects produced upon patients by the nitrous oxide prepared from it. Had the silver test been used the presence of the chlorine would have been revealed.

There is greater need for care in the examination of the ammonium nitrate when it has been prepared by the reaction between ammonium sulphate and potassium nitrate—a process which for commercial reasons is sometimes resorted to by manufacturers. The reaction is as follows:

$$\underset{\text{Ammonium sulphate.}}{(NH_4)_2SO_4} + \underset{\text{Potassium nitrate.}}{2KNO_3} = \underset{\text{Ammonium nitrate.}}{2NH_4NO_3} + \underset{\text{Potassium sulphate.}}{K_2SO_4}.$$

The resultant products, which are in solution, are separated by a method dependent entirely upon their different rates of crystallization. Unless this process is conducted with the most absolute care, there is always the possibility that the ammonium nitrate thus prepared may be contaminated either with potassium nitrate or potassium or ammonium sulphate; with the further possibility that, as the latter salt is prepared by neutralizing with sulphuric acid the ammoniacal liquor obtained in the manufacture of illuminating gas, it may be found to contain various pyroligneous impurities deleterious in character.

Apparatus for Making and Storing Nitrous Oxide.—A good form of apparatus for the preparation of nitrous oxide is shown in Fig. 14, p. 147. It consists of a stand and chain for suspending the retort, a heating apparatus, three wash-bottles, and a gasometer.

The retort figured is really the old alembic with an invagination in the upper part, or "head," intended to condense the steam arising during distillation and receive the moisture formed by such condensation, thus in an imperfect manner fulfilling the purposes of the worm condenser. At the high temperature required to decompose ammonium nitrate the head of the alembic becomes too much heated to serve as a condenser, except in a very imperfect degree. The larger surface which the invagination presents to the air aids to a limited extent in keeping the head, as well as the beak connecting it with the wash-bottles, cooler than the lower part, or body, of the alembic, and thus overheating of the rubber tubing used in making the connection is somewhat controlled. In the usual form of glass retort the same object is effected by the greater relative length of its beak. The alembic, however, will be found less cumbersome in use and less liable to fracture. Its head contains a tubular orifice for the introduction of the ammonium nitrate, this being closed by a cone-shaped rubber stopper.

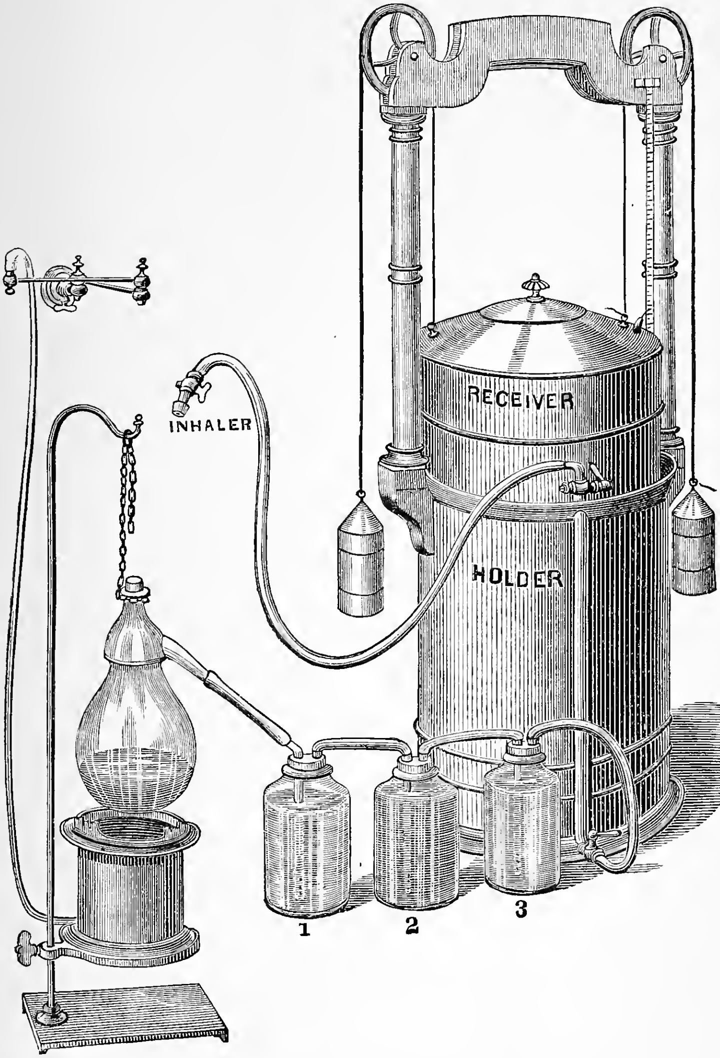
The height of the alembic is 11½ inches, its capacity 5 pints. The height of the stand to which it is suspended is 33⅓ inches. To the stand is attached a bracket upon which the heating apparatus may be placed and lifted or lowered at pleasure.

Wash-bottles.—The wash-bottles represented in the cut are 11¾ inches in height and have a capacity of 9½ pints. They are closed with cone-shaped rubber stoppers, each containing two perforations large enough to admit, under pressure, glass tubes half an inch in diameter. These tubes are intended respectively for the admission and exit of the gas. The admission or dip tubes are made long enough to pass nearly to the bottom of the wash-bottles; the exit tubes are much shorter, as, in order that the outflow of gas may not be obstructed, it is necessary that their lower ends should be entirely above the surface of the washing fluids. The lower end of the dip tube is sometimes made somewhat bulbous, and with numerous small perforations designed to break up the gas in small volumes, and thus secure its more thorough washing. As, however, in practice the gas is usually found to escape through the more accessible of these openings, leaving the others unused, the device is not of much practical utility.

The amount of fluid placed in each bottle should be so graduated that in no case shall the end of the dip tube be more than two inches below its surface, as where this depth is exceeded the column of fluid which will rise in the tube will offer so much resistance to displacement by the gas as to prevent free delivery.

The upper ends of both tubes are bent at right angles. The dip tube

FIG. 14.



Nitrous Oxide Gas Apparatus.

in bottle No. 1 is connected directly with the retort, and the short or exit tube in bottle No. 3 with the gasometer. From bottle to bottle the same relative arrangement is followed. These connections are all made by stout rubber tubing of suitable length and calibre.

The gasometer is constructed of sheet zinc, japanned to prevent chemical action. It may be made of any required capacity, from fifty gallons upward, according to the needs of the operator. It consists of the usual water-holder and gas-receiver, with pulley-and-weight attachment for counterbalancing. Before filling the gas-receiver all air should be expelled from it by opening its exit tube and sinking it in the holder, the latter being previously filled to within two or three inches of its top with pure spring or river water.

Washing Fluids.—The washing fluids used are the following: For bottle No. 1 (nearest the retort), pure cold water; for bottle No. 2, a solution of caustic potassa, made in the proportion of one drachm of the alkali to two pints of cold water; for bottle No. 3 (nearest the gasometer), a solution of ferrous sulphate, made in the proportion of two ounces of the salt to a pint of water. This solution should be made and kept cold. For greater security a fourth bottle, containing pure cold water, is sometimes added to the series.

Testing Joints.—When all connections are made between the retort, wash-bottles, and gasometer, accuracy of adjustment should be tested by blowing air through the whole system, beginning at the retort. If the proper adjustments have been made, the air will freely bubble up through the bottles and the gas-receiver will be lifted. The absolute impermeability of all joints, stopcocks, etc. is essential to success in making and storing pure nitrous oxide; and the fact that such impermeability exists should be definitely ascertained before the decomposition of the ammonium nitrate begins.

Quantitative Results.—The quantity of this salt to be placed at one time in an alembic of five pints' capacity should not exceed a pound and a half. This will make about fifty gallons of gas, the average product from a pound of ammonium nitrate being from twenty-five to thirty gallons, this amount varying with the temperature at which it comes over, as well as that at which it is maintained in the receiver. The quantity absolutely secured is very generally reduced by unavoidable wastage and by being taken up into solution by the water of the wash-bottles and gasometer.

Heating Appliances.—For heating purposes the ordinary illuminating gas, so mixed with air as to ensure perfect combustion, is convenient and effective. Many patterns of burners are now in the market. Instead of these a charcoal furnace—or, indeed, any of the usual sources of heat—may be utilized, the retort, suspended by its chain, being swung for a time to and fro through or over the flame, which is of course graduated as to size and intensity to guard against a too sudden or unequal heating of the glass surface.

Temperature of Decomposition.—Although the temperature at which the decomposition of ammonium nitrate is effected is of great importance, a thermometer is rarely employed as a guide: the experienced operator readily determines by such obvious physical phenomena as the greater or less violence of ebullition of the melted salt, the colorlessness of resultant products, etc. whether the decomposition is proceeding satisfactorily or otherwise. Indeed, the use of a thermometer in the retort is attended with considerable inconvenience and risk, as it is necessary that the bulb should be kept immersed in the ammonium nitrate, for the reason that the temperature of the vapor or gas in the head of the retort is in all safe distillation 120° or 130° below that at which the salt decomposes, the amount of heat which this difference represents being absorbed by the products of decomposition as they pass into the state of gas or vapor; hence a thermometer in the head of a retort will rarely indicate a temperature of more than 200° F., even when distillation is proceeding most actively.

When an open flame is employed, its size must be gradually lessened or its distance from the retort increased as the volume of ammonium nitrate diminishes by decomposition, because just as a small flame, which would simply warm a large metallic mass, would heat to incandescence a piece of foil or wire, so the amount of heat which in a given time is rendered latent in liquefying and volatilizing a pound of ammonium nitrate far exceeds that which can be safely applied when the pound has been reduced to an ounce.

Between 270° F. and 300° F. the ammonium nitrate slowly sublimes without decomposing and without becoming fluid, a film of the sublimed crystals collecting in the head or beak of the retort or alembic. At 320° F. it slowly melts and decomposes, as evidenced by the appearance of occasional bubbles of gas. Between 340° and 480° F. the decomposition proceeds very rapidly, and is followed by free ebullition. The character of this phenomenon is a safe guide as to the nature of the decomposition which is being effected. It should never amount to a violent boiling, dashing the melted mass to the sides and top of the retort, but should be a free, gentle, and uniform bubbling of the gas up to the surface. A too violent ebullition indicates quite as unerringly as would a thermometer a temperature so high that combinations of nitrogen other than nitrous oxide may be formed, while the actual presence of such combinations is made manifest by certain changes of color in the contents of the retort.

Deleterious Products.—The exact nature of some of the chemical combinations in question has not been definitely determined. Ammonia and ammonium nitrite may be produced, but their vapor, like nitrous oxide itself, is colorless. A white cloudiness which often appears is probably due to the volatilization of ammonium nitrate, and possibly also ammonium nitrite formed from the nitrate. The red fumes which are always given off at a sufficiently high temperature are known to be due to the presence in the retort of either nitric oxide or nitrous acid.

Whatever may be the exact chemical structure of the products of the decomposition at the higher temperatures of ammonium nitrate, all are irritant and irrespirable, and some of them poisonous gases or vapors. These, if produced only in small quantities, may be removed during their passage through the chemical solutions in the wash-bottles.

Purification.—The pure cold water in bottle No. 1 will condense the steam which comes over with the gas, and will dissolve solid particles of ammonium nitrate or ammonium nitrite which may escape from the retort. Ammonia too will be taken up into solution.

The caustic potassa in bottle No. 2 combines with nitric and nitrous acid, carbonic acid, and chlorine.

The ferrous sulphate in bottle No. 3 will absorb any ammonia which may have escaped from the other bottles, but its chief value is that it has a special affinity for nitric oxide (NO), with which, according to Péligot, it forms the following compound: $2FeSO_4 + NO$. This compound, however, is readily decomposed by heat; hence the necessity for keeping bottle No. 3 and its contents cool.

While these chemical agents are reasonably certain to remove all products of decomposition other than nitrous oxide, provided they be not produced in too great volume, the best assurance of safety lies in so regulating the temperature that only that gas and water shall be formed. This is especially necessary when the gas is to be at once liquefied, because there is then but little opportunity afforded for the removal of nitric oxide by absorption in the water of the gasometer; which absorption will be readily effected if the water contains air, as in greater or less proportions it always does, the absorption being dependent upon the oxidation of the nitric oxide (NO) to the nitrogen dioxide (NO_2), which is readily soluble in water.

The wash-bottles should not be connected with the gasometer until the nitrous oxide has begun to pass freely through them, thus expelling the air which they contain. When the gasometer is to be freshly charged, however, or when it is known to contain either impure gas or atmospheric air, the escape-pipe should be opened, the wash-bottles connected, and the newly-formed gas be allowed to pass through and escape from not only them, but the receiver as well. After a few minutes, if the nitrous oxide is coming over freely, only pure gas will remain and the escape-pipe may be closed.

Pressure during Distillation.—As the initial velocity of the gaseous molecules entering the gasometer supplies the lifting force necessary to raise the receiver, and as this force is transmitted equally in all directions and exerts the same pressure on all equal surfaces, the original impulse or series of impulses, although very slight, is, when thus multiplied, sufficient, if time be given, to lift the largest receiver, when properly counterbalanced, without any notable increase of pressure inside the retort. Care should be taken, however, not to pass the gas into the receiver beyond its storage capacity, as then the pressure is at once intensified, and either leakage at the joints or fracture of the retort may result.

Wastage of Gas.—As already stated, some wastage of gas is occasioned by its being taken up into solution by the water in the gasometer: this loss, as has been seen, varies with the temperature of the water, the amount dissolved being less when the water is warm than when it is cold—a fact which indicates the advisability of keeping the gasometer in a moderately warm room. Loss in this direction, however, becomes inconsiderable when the water has once been saturated, as it will be when contact has been maintained for several days.

Deterioration.—A more important consideration is the deterioration of the nitrous oxide which must result from such prolonged contact, for not only is nitrous oxide taken up by the water, but the gases with which all ordinary spring and river waters are charged become, by the laws of diffusion, mixed with the nitrous oxide, so that in a few days the latter becomes unfit for use. If administered, a larger amount of the gas and a longer time are required to produce anæsthesia, and the inhalation is followed by headache and general malaise if by no more alarming symptoms. The gases present in fairly pure water are oxygen, nitrogen, and carbon dioxide. When sewage contaminations are present, chlorine, sulphuretted hydrogen, and such volatile organic acids and alkaloids as are among the products of the putrefactive decomposition of organic matter will be found, and in no inconsiderable quantity. Under no circumstances should water so contaminated be placed in the gasometer.

Storage of Gas.—The water in the holder, if pure, need not be changed, but loss by evaporation will necessitate occasional additions. When stored with nitrous oxide, with which gas it speedily becomes saturated, putrefactive changes in the water are never observed. This is probably due to the presence of the gas, which is antagonistic to germ-life. An operator of large experience, Dr. Thomas, states, however, that he always observes a deterioration in the quality of the nitrous oxide when it has been stored over water which has remained in the holder more than three weeks, the effects of the gas when inhaled being unsatisfactory in character. He therefore changes the water at frequent intervals. This, however, is not the usual practice, and the effects mentioned by Dr. Thomas have not been noted by other specialists.

As a rule, it is better not to administer nitrous oxide immediately after its collection, as any nitric oxide which may have escaped solution or chemical arrest in the wash-bottles will, after a few hours of contact, be dissolved in the water of the gasometer, which always contains free oxygen absorbed from the air of the room.

The temperature at which the gas is stored may easily be too high for immediate administration if the proper precautions have not been observed in its preparation. Usually, however, this is not the case. Owing to the presence with it of so large an amount of steam, the gas passes into the first wash-bottle at a temperature not much above 212° F., and by the time it has reached the gasometer its temperature will have been reduced to about that of the washing fluids through which it has passed. With these fluids at a temperature of 40° F. at the beginning of the passage of the gas through them, the writer has observed a rise of only ten degrees in the temperature of the contents of the third wash-bottle after all the gas resulting from the decomposition of a pound and a half of ammonium nitrate had passed through it. Were the process to be indefinitely prolonged, however, it is obvious that ultimately the temperature of the gas as it passed into the receiver would become but little less than that in the retort; which condition would, of course, absolutely inhibit its administration.

Temperature for Administration.—Under all circumstances the gas should be thoroughly cool, as it is a matter of clinical experience that when given even moderately warm the effects are not so satisfactory as when administered at the lower temperature—a result doubtless due to the greater rarefaction of the gas when heated, the volume of this, as of all other gases under a constant pressure, varying, in accordance with the law of Charles, directly as the absolute temperature.

Assuming that the number of molecules of nitrous oxide in the whole amount of gas made remains the same, however much the volume of the gas may be amplified by heat or diminished by cold, it follows that when the volume is increased the molecules must be more widely separated the one from the other, and that, as a consequence, a smaller number of these will enter the lungs at each inhalation. Thus, fewer being admitted, fewer will be absorbed in a given time, and insufficient dosage must result in insufficient anæsthesia.

Liquefied Nitrous Oxide.—As already stated, nitrous oxide assumes the liquid form when subjected to a pressure of fifty atmospheres at a temperature of 40° F. Gas stored in this condition may be kept for an indefinite period perfectly free from all sources of contamination. This advantage, among others, has caused its general introduction into dental practice, and, with the exception of those who daily use large quantities of the gas, but comparatively few now resort to the older methods for its manufacture and storage.

The making of nitrous oxide upon the large scale required for commercial purposes differs only in detail from the processes already described. The retorts are made of iron lined with porcelain; the tubing leading to the wash-bottles is also of iron, with a segment of glass introduced through which the appearance of the products of decomposition may be examined.

The gas as formed is conducted into a large iron gasometer, whence it passes to the condensing pump, of which there are various forms in use. This must be constructed with the utmost precision of adjustment, as the absolute impermeability of all joints and the perfect working of valves are necessary to prevent the wastage of gas.

Charging Cylinders.—The nitrous oxide passes directly from the pump into wrought-iron cylinders of varying size, into the smallest of which one hundred gallons, and into the largest five hundred gallons, of gaseous nitrous oxide may be condensed. As the pressure to which the cylinders are subjected is enormous, the utmost care is requisite in the selection of material for their manufacture, iron of the highest possible tensile strength being employed and all joints being thoroughly welded. Each is tested by pressure far exceeding that to which it will be subjected in the storage of nitrous oxide.

The cylinder to be charged is connected directly with the condensing pump, and placed in a tank filled with ice and water, to keep the temperature of the gas down to the required point. Owing to the large amount of heat evolved from the nitrous oxide in its passage from the gaseous to the liquid state, the process cannot be hastened, and with a condensing pump operated by steam about fifteen minutes are required to fill a one-hundred-gallon cylinder.

Each cylinder is provided with a high-pressure gas-valve, which when in order will effectually seal its contents, and through which the gas may be withdrawn from time to time in such quantities as may be needed.

Tests for Nitrous Oxide.—The purity of any given volume of nitrous oxide gas may be determined by the following tests:

Acids.—As a general test for all acid contaminations, pass the gas through a solution of litmus: any acid vapor present will turn the litmus from its natural blue to a red color.

Alkalies.—A solution of litmus reddened by an acid may be used as a test for alkaline impurities, such as ammonia, etc.: by these the blue color is restored to the solution.

Carbonic Acid.—Lime-water will give with this acid a white precipitate of calcium carbonate.

Chlorine and Hydrochloric Acid Gas.—These and the chlorides will cause a precipitation of silver chloride from a solution of silver nitrate.

Nitric Oxide.—This gas will give a dark-brown color to a solution of ferrous sulphate.

Iodine and Starch Test.—The presence of ozone, chlorine, hypochlorous acid, and nitrogen oxides higher than N_2O will be indicated very delicately by placing in the gas a paper freshly dipped in a solution of potassium iodide in liquid starch: the paper will turn blue upon the liberation of iodine by any of the above substances.

The writer has carefully tested the liquid nitrous oxide furnished by by the S. S. White Manufacturing Company, Philadelphia,[1] and has failed to demonstrate the presence of any impurities whatever. For all practical purposes it may be considered as chemically pure. The same is probably true of the liquid gas prepared elsewhere.[2] These results are doubtless largely due to the care exercised in the manufacture of ammonium nitrate and in its distillation.

Pressure as a Purifying Agency.—The claim is frequently made that the liquefaction of nitrous oxide is in itself eliminative of such other gases as require a higher pressure to effect their reduction from the gaseous to the liquid state. That a *separation* of mixed gases may be effected by subjecting the mixture to varying rates of pressure is unquestionable, but the elimination of the separated gas is not a necessary result of its separation, and, withal, is not so readily accomplished.

Of all known gases, nitric oxide is one of the most difficult to liquefy, a far greater pressure than fifty atmospheres being necessary. Assuming that nitrous oxide under pressure is contaminated with nitric oxide, the latter substance would retain its gaseous form under the pressure of fifty atmospheres, which would completely liquefy the nitrous oxide. But, as already intimated, this separation can be a matter of but little practical consequence so long as the two substances still remain in, and are drawn off from, the same cylinder or other receptacle into which they have been forced.

Thus confined in the cylinder, a minute amount of nitric oxide might possibly be held in solution in the liquid nitrous oxide, but the greater volume will probably be found intimately mixed with the vapor of nitrous oxide, which always exists above the liquid portion in the cylinder.

On this hypothesis it would seem that if this contaminated residual nitrous oxide vapor is allowed to escape before applying the remaining

[1] To this company the writer is indebted for the courtesy of a full explanation of their methods of preparing the gas.

[2] In France tests for impurities applied by M. Cazeneuve gave equally negative results. He states (*Lyon Médicale*, Dimanche, 2 Novembre, 1884) that all specimens of liquefied gas he has examined are almost absolutely pure. Only a trace of oxygen (probably from air) is found, and there is an entire absence of deleterious nitrogen compounds.

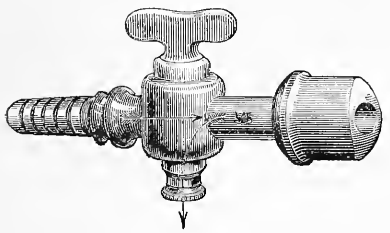
contents of the cylinder to anæsthetic purposes, the *elimination* of nitric oxide would in a great measure be effected. As the writer is not aware that this practice is systematically followed by manufacturers, it can be recommended as a wise precaution on the part of administrators.

Inhaling Apparatus.—Nitrous oxide may be inhaled either directly from the gasometer by means of a mouthpiece with suitable valves and tubing, or it may be drawn into an air-tight bag provided with a mouthpiece and stopcock, and be thence drawn directly into the lungs of the patient. The latter method was the earlier one, and is still adhered to by some operators. It is, however, open to the objection that unless the mouthpiece be provided with valves the products of expiration will, the nasal passages being closed, pass back into the bag, diluting and contaminating its contents. In practice, however, the operator can to a great extent obviate this objection by compressing with his fingers the nose of the patient during the inspiratory movement and removing the pressure during expiration, thus allowing the greater portion of the lung contents to escape through the nasal tract. By practice considerable dexterity in the performance of this valvular manipulation can be acquired, the chief difficulty being in so timing the compression and release of the nose as to make these movements synchronous respectively with the inspiratory and expiratory acts.

For convenience and effectiveness, however, a system of valves working automatically in the inhaler is to be preferred. These valves, in whatever manner made, should be so perfectly adjusted as to, as nearly as possible, absolutely exclude atmospheric air while admitting full volumes of the anæsthetic gas and preventing the return into the gas-bag or receiver of the products of expiration.

A simple and yet effective form of valved inhaler is that seen in Fig. 15. It is made of hard rubber, the inner diameter of the tube being somewhat over half an inch. The entrance and exit valves are made of thin disks of hard rubber. With the stopcock seen in the illustration the supply of gas can be regulated at the will of the operator. To prevent the admission of air by way of the nasal tract the nose of the patient must be compressed by the operator during the administration of the gas. A clamp may be used, but the fingers are more effective.

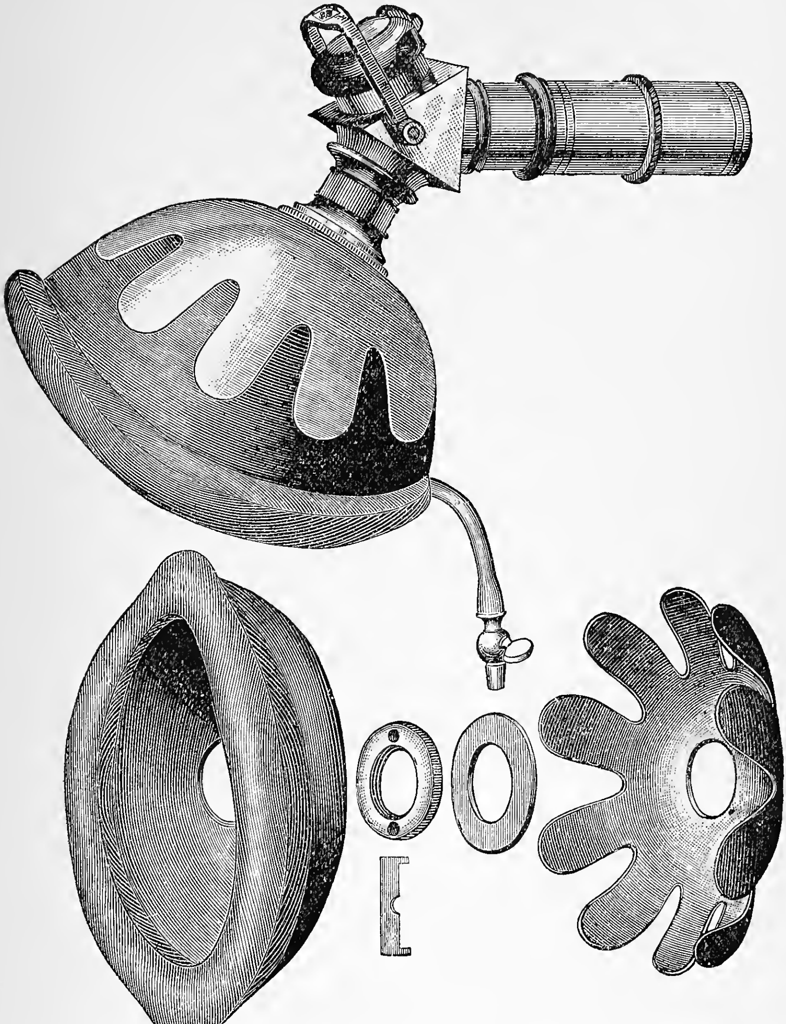
Fig. 15.



Hard-rubber Inhaler.

Next in importance to the proper construction and perfect working of the valvular apparatus is the adaptability of the mouthpiece to the uses for which it is designed. A frequent defect is the small calibre of the tube. For adults this should always be between a half and three-quarters of an inch in diameter, so that full and free volumes of gas may pass into the lungs at each inspiration. As the adult human trachea has a diameter of from three-fourths of an inch to an inch, the desirability of approximately conforming to this natural measurement

Fig. 16.



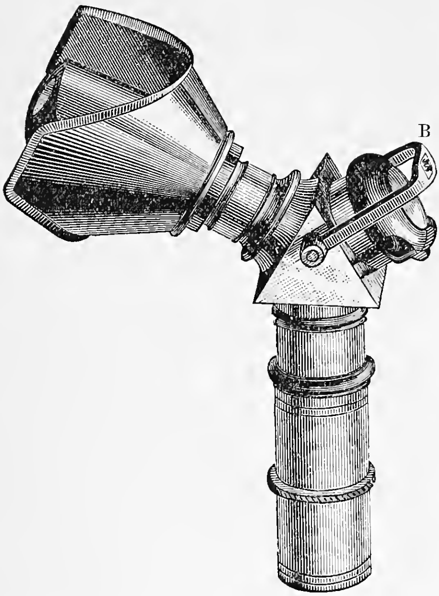
Improved Flexible Facepiece.

is apparent. The hard rubber of which mouthpieces are constructed is a material admirably adapted to the purpose, it being light, strong, and cleanly.

Many inhalers are provided with a metallic mouth-hood, such as that seen in Fig. 17. The writer has not found mouth-hoods generally advantageous: they completely obscure the lips from view, so that changes in their color cannot be observed, and as they, of course, do not accurately adapt themselves to all facial contours, air will frequently pass beneath them and into the lungs unless the lips of the patient be tightly compressed around the mouthpiece; and this the presence of the hood prevents the operator from definitely determining, thus introducing an element of incertitude into the anæsthetic procedure.

A much more practical form of hood or facepiece is the "improved flexible facepiece"[1] seen in Fig. 16. This hood is designed for use without a mouthpiece. It is made of soft rubber, with an inflatable edge-cushion attached to a metal frame which is screwed to the inhaler. This cushion may be inflated by means of the little tube seen in the figure, which tube is provided with a closely-jointed stopcock. The flexibility of this hood permits of its accurate adjustment to the face, and as it covers the nose, compression of that organ either with the fingers or with a clamp can be dispensed with. In cases of hare-lip or when from any cause there is immobility of the temporo-maxillary articulation, the flexible hood is of admirable service; but for general purposes the writer prefers the plain mouthpiece, in the use of which neither the lips nor any other portions of the face are hidden from view.

Fig. 17.



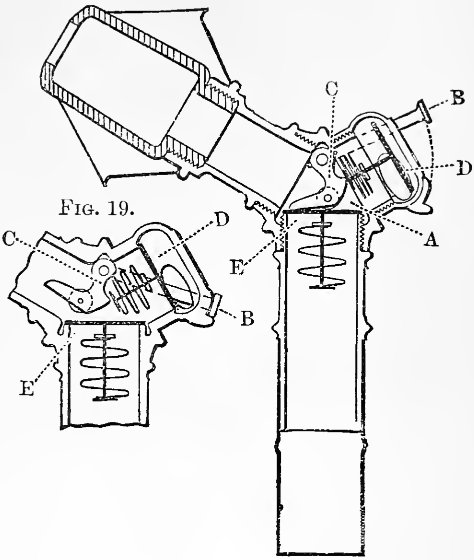
Divested of the mouth-hood, which may readily be detached, the inhaler seen in Fig. 17[2] is admirably adapted for its purpose. With the exception of the mouthpiece and two valves, which are of hard rubber, it is constructed entirely of metal.

Both the inhaling and exhaling valves are placed in a prism-shaped casting, A (Fig. 18), which is an improvement on the two-way cock usually employed, and which affords the additional advantage of an angle in the apparatus whereby the tubing is permitted to fall close to the breast of the patient, out of the way of the operator. The valves are controlled externally by a stirrup or bow, B (Figs. 17, 18, and 19), to which is attached, inside the prism-shaped box, by means of a shaft, a foot-shaped cam, C. When the bow is pushed upward in the position shown in Fig. 18, the heel of the cam presses against and holds open the exhaling valve, D, allowing free passage of the air to and from the lungs, while at the same time the toe of the cam closes the inhaling valve, E, and prevents the escape of gas from the reservoir. When the bow is pushed backward, as shown in Fig. 19, both valves are thrown into

[1] Of the S. S. White Dental Manufacturing Company.
[2] Gas-Inhaler No. 2 of the S. S. White Dental Manufacturing Company.

Fig. 18.

Fig. 19.

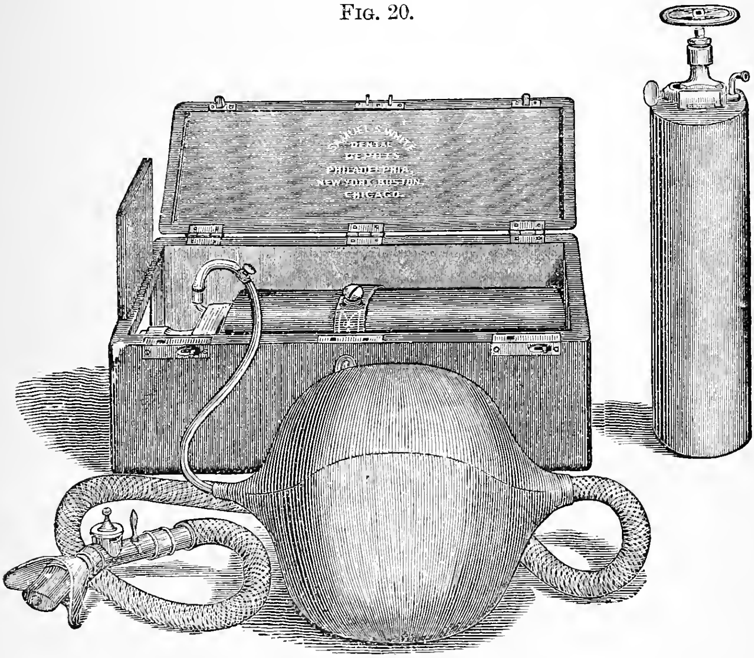


action, and become subject to the slightest breath of the patient, inhalation opening the gas-valve and closing the air-valve, exhalation producing the reverse effect.

When a gas-bag is used, it should be thoroughly emptied of air before the nitrous oxide is passed into it: this can be quite perfectly accomplished simply by the inhalation of its contained air by the operator. The same method should be adopted with the delivery-pipe when the gas is to be inhaled through it direct from the receiver: a short pipe is readily emptied in this manner, and, as it is undesirable that any great length of tubing should be used, the gasometer should not be placed more than five or six feet from the patient.

In the use of the liquefied nitrous oxide the gas may be drawn from

Fig. 20.

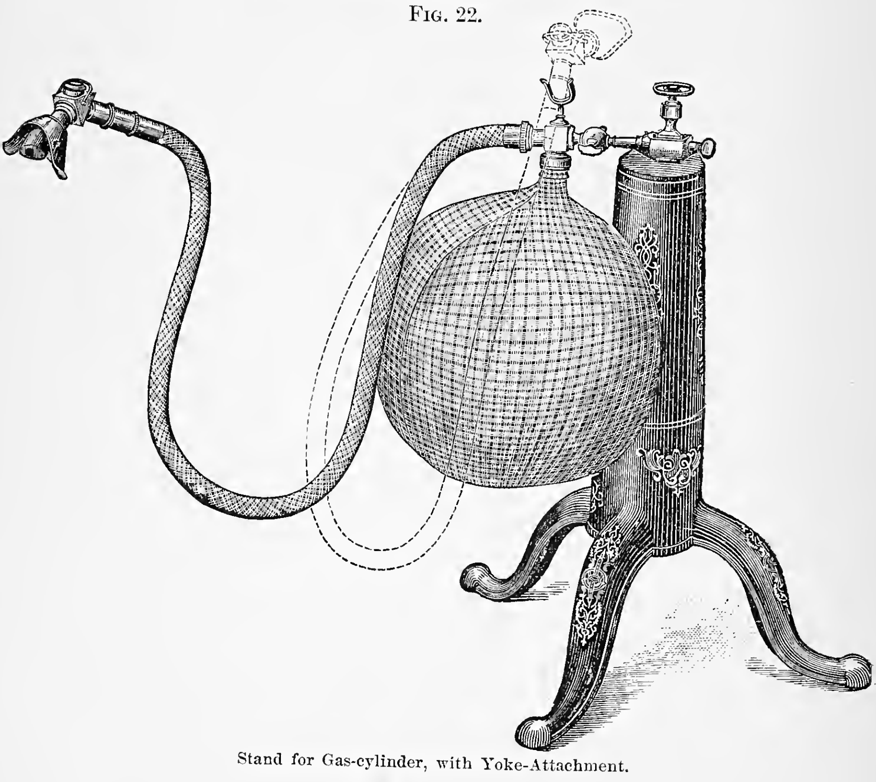


Surgeon's Case.

FIG. 21.

Upright Surgeon's Case.

FIG. 22.

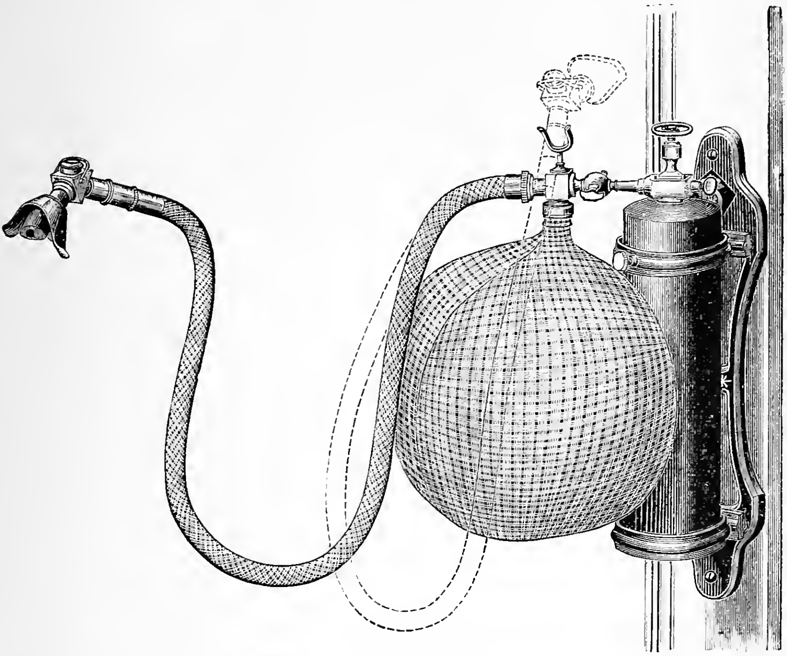


Stand for Gas-cylinder, with Yoke-Attachment.

the cylinder directly into an air-tight bag of suitable capacity—six to eight gallons. For greater convenience this bag is generally connected by tubing at either end with the cylinder and inhaler respectively. By this arrangement a fresh supply of gas can, when needed, be passed into the bag without the removal of the inhaler from the mouth of the patient.

In Figs. 20 and 21 are seen two forms of apparatus for the storage and administration of liquefied nitrous oxide, which forms, being portable, are well designed for the use of the general surgical practitioner. In Fig. 20 the cylinder containing the gas is placed in the case in a horizontal position. In Fig. 21 it stands on end, and is somewhat more accessible.

Fig. 23.



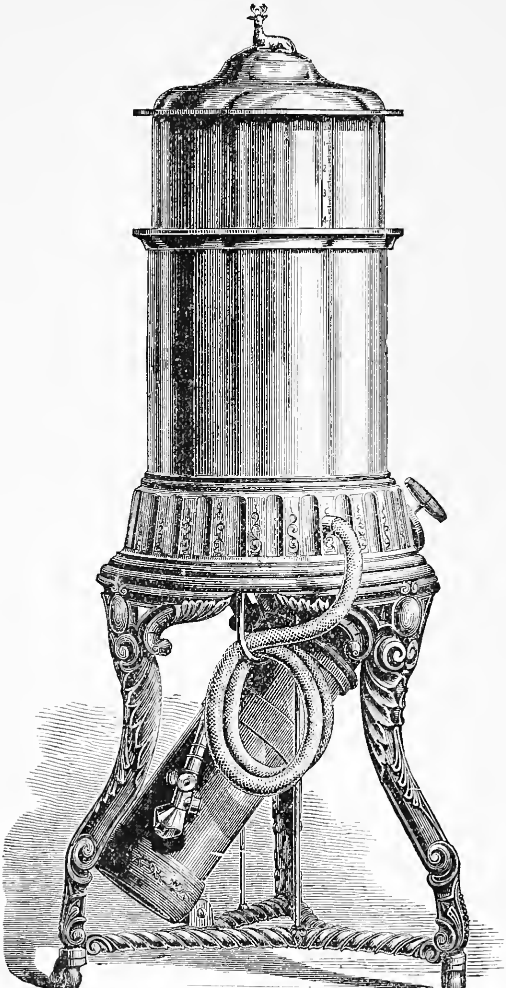
Wall-Bracket for Gas-cylinders.

Figs. 22 and 23 represent forms of apparatus adapted for office use. Fig. 22 shows a metallic stand containing the cylinder, with the gas-bag held in position by a "yoke attachment." The yoke is provided with a holder for the inhaler when not in use, as shown in the dotted lines. In Fig. 23 is seen a form of wall-bracket for a gas-cylinder, the latter having the same equipment as that seen in Fig. 22.

Another form of apparatus now coming into extensive use is that seen in Fig. 24. It consists of a small metallic gasometer with a storage capacity of about ten gallons of gas. Into this, instead of an elastic bag, the gas is passed by means of the key seen on the right of the figure. By simply turning the key the operator has under his control all the gas in the cylinder, a scale graduated in gallons and fractions of a gallon, attached to the bell, enabling the operator to determine how much gas has been used. Surplus gas can remain in the gasometer for several days if necessary, and still be available for use.

The diagram (Fig. 25) represents a sectional view of a Johnston gasometer. Two metallic cylinders, A A, are arranged concentrically to form a water-holding space between their proximal walls, while a third cyl-

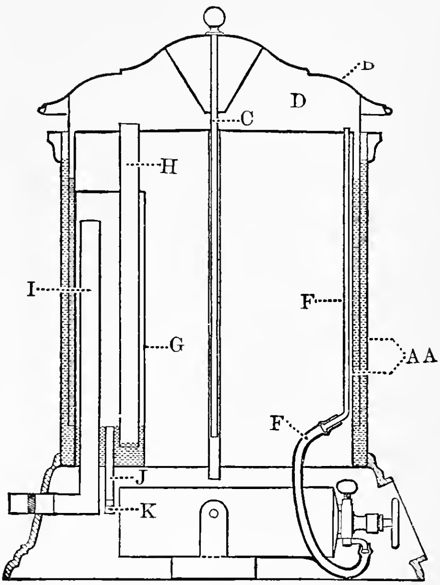
FIG. 24.



Gasometer and Stand.

inder, having a cover, B, and a guide-rod, C, attached to the cover, is lowered into the water-space as a seal between the cylinders and to form a gas-chamber, D, at the top. The inner cylinder is provided with a central tubular cavity, closed at the bottom, to receive the guide-rod of the cover. It is obvious that the chamber, D, will be enlarged or diminished according to the volume and presence of the gas which rises to the chamber from the iron cylinder, E, beneath the gasometer, when the valve is opened, through the connecting tube and pipe, F, F. The gas is conducted to the inhaler from the chamber, D, through a closed cylindrical water-vessel, G, attached to the wall of the inner cylinder, and provided with an inlet-pipe, H, and an outlet-pipe, I; which latter is carried to the outside at right angles to the gasometer, and receives the tubing which conducts the gas to the inhaler. This closed vessel, G, is also provided with a water-outlet or overflow, J, and the whole forms a very simple and effective trap for shutting off the gas when not inhaled. In operation it is only necessary, before the cover is placed in position, to pour into the water-space between the cylinders enough water to nearly fill it, and into the inlet-pipe, H, sufficient water to overflow the outlet, J, of the trap, the rubber stopper, K, of the latter being removed for that purpose and replaced when the overflow has ceased. Then insert the cover and open the valve of the iron cylinder beneath. The vacuum in the vessel, G, produced by each inhalation is immediately filled by the gas passing through the water and upward to the outlet, I; the instant that inhalation ceases the gas is arrested and confined at the water-level in the trap. This gasometer is also provided with a gauge, which indicates by gallons the quantity of gas in the reservoir.

Fig. 25.



Preparation of the Patient.—The almost entire immunity from fatality which has hitherto attended the administration of nitrous oxide for anæsthetic purposes has resulted in a carelessness in regard to the preparation of the patient which is to be deprecated. Even with nitrous oxide anæsthesia is a condition of danger, and while this is less than with any other known anæsthetic, still an utter disregard of all the rules ordinarily to be observed in the use of other agents of the same class is not to be justified.

In order that respiration may be free, and that prompt measures may be taken for the rescue of the patient from syncope or asphyxia, either of which may occur during the operation, the clothing should be loosened. As nausea is of very rare occurrence, an absolutely empty stomach need not be insisted upon, but it should not be distended with food, neither should the bladder or intestines be overloaded. As a rule, it is better that a period of from two to four hours should have elapsed after the last meal. That all foreign substances should be removed from the mouth is, of course, self-evident. The one great departure from the general laws governing the anæsthetic procedure is in the position of the patient: with nitrous oxide gas the sitting posture may, for short operations, be maintained throughout. This departure from a general principle is justified by the fact that the heart and circulation are but slightly influenced by the agent, and that it at no time exerts a specifically depressing power over the cardiac ganglia. The head of the patient should be bent forward rather than backward, as thus placed there is less danger that the tongue will fall back and close the glottis. The hands should be spread out in full view, either upon the lap of the patient or upon the arms of the chair in which he is seated, thus facilitating the observation of those changes of color which are so significant in narcosis with this agent.

Props.—Prior to the administration of the gas a gag or prop should be placed between the teeth of the patient. This is made necessary by the muscular rigidity which usually marks the stage of complete anæsthesia when nitrous oxide has been employed. When the operation required is the extraction of teeth, much valuable time might be lost in forcing apart the jaws of the patient were the prop not in position. But even for operations other than in the mouth its use cannot, ordinarily, be safely dispensed with, as by keeping the mouth open it enables the operator to grasp and draw forward the tongue or thrust his fingers into the fauces when profound stertor or other indications of approaching asphyxia indicate the necessity for the removal of mechanical obstructions in the air-passages or of reflex stimulation of the respiratory function.

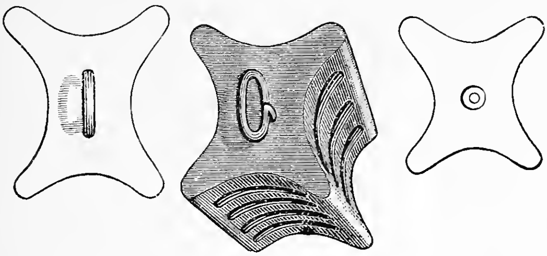
The prop should always, when possible, be placed between the molars, and in cases of extraction upon the side opposite to that from which the tooth is to be removed. Placing it between the incisors is, of course, for every reason undesirable: it would interfere with the introduction of the mouthpiece when one is employed, and if pressed upon too strongly might cause the fracture of these relatively frail and conspicuous teeth; indeed, one of the uses of the prop is that it affords a good degree of security against the occurrence of this accident through pressure upon the mouthpiece of the inhaling apparatus.

The length of the prop must be regulated by the conditions of the case, the extent to which the jaws can be parted varying greatly in different individuals, even in health, and being often seriously limited by pathological states of the teeth or their investments. In cases of simple extraction all that is required is that the jaws shall be sufficiently separated to permit the free introduction of the extracting instrument and the safe removal of the tooth: all extension beyond this is unnecessary and, if discomfort is occasioned, harmful.

The prop should be made of hard wood, hard rubber, cork, or of some other substance not easily fractured, and it should be grooved or serrated in order that it may not readily slip from between the teeth. For security against accident the prop should invariably have attached to it a strong string, so that in case it should become displaced and fall into the fauces it may readily be removed. At least one case of fatality is attributable to a neglect of this precaution.

One of the most practical forms known to the writer is that devised by Dr. F. T. Van Wert of Brooklyn, N. Y., and illustrated in Fig. 26.

A FIG. 26. B



It is constructed of tough black rubber, and is deeply grooved upon its four sides, each groove being serrated. In general outline the prop is wedge-shaped, A showing in cross-section the large end, B the small end of the wedge. Thus the prop is made to conform to the dimensions of the space between the teeth when the jaws are opened, so that when the small end of the wedge is placed between the upper and lower molars the large end will be in contact with the more widely separated upper and lower bicuspids. As the diameters of the wedge are unequal, this single prop can be adapted to quite a wide range of requirement as to the separation of the jaws, and its form admirably adapts it to those cases in which, owing to the absence of teeth upon one side of the mouth, it is necessary to place it in contact with the gum-tissue of the edentulous alveolar ridges. A looped wire strongly bolted to the prop affords a convenient means of attachment for the string.

PHYSIOLOGICAL EFFECTS OF NITROUS OXIDE.—The first obvious impression resulting from the inhalation of nitrous oxide is upon the gustatory sense by the characteristically sweetish taste of the gas. While, when perfectly pure, nitrous oxide is not irritative in the ordinary acceptation of the term, still the first full, deep inhalations produce in the respiratory tract an indefinable sense of oppression, sufficiently marked in character to frequently cause patients to thrust away the inhaler. These sensations are probably referable to the displacement of oxygen by the nitrous oxide, but may perhaps be in a measure due to the impact of the molecules of this gas against the delicate epithelium of the bronchial passages, to which they present themselves as foreign bodies, although not so markedly different in size, form, and chemical affinities from those inhaled in normal respiration as to produce distinctly irritative results. As, however, the nerves of sensation in the lung tract become almost immediately locally anæsthetized, the sense of discomfort is evanescent in character, and is speedily replaced by a feeling of well-being deepening into a glow of pleasurable emotion: a disposition to merriment and laughter is experienced. This in all its essential features corresponds to the first stage of ether narcosis, the stimulant stage or the stage of functional excitation.

If the administration of the gas be discontinued at this point, the exaltation of functional activity will sometimes be manifested in a very marked degree. The most violent muscular movements may be executed, often to the injury of the patient himself or of bystanders: violent rushes at imaginary foes, blows dealt against them; declamatory gestures; oscillations of the head from side to side with a violence threatening dislocation of the vertebræ; excessive laughter, drunken volubility, and maudlin weeping are among the effects, physical and psychical, which in former times were frequently witnessed when the gas was inhaled solely to produce intoxicant effects for purposes of amusement or of physiological experiment. As ordinarily administered for anæsthetic purposes, however, the stage of depression follows so swiftly upon the condition of excitation that opportunity is not afforded for the development of these phenomena, and it is but rarely that a patient requires the exercise of force for his control. Were the progressive phases of anæsthesia evolved as slowly with nitrous oxide as with ether, it is possible that restraint would be necessary quite as frequently with the former as with the latter agent.

As administered for anæsthetic purposes, however, the stimulant stage rapidly merges in the second or narcotic and anodyne stage of anæsthesia, during which a tingling sensation, followed by numbness, is felt over the entire cutaneous surface, the brain seeming to swim in dizzy and ever swifter gyrations; finally, in a whirl of confused and incoherent ideas and impressions consciousness is lost, and the narcosis deepens into the beginning of the third or true anæsthetic stage.

Effects on Circulation and Respiration.—The circulatory system, except in extreme narcosis, is, as a rule, but little disturbed; the pulse, if excited before the inhalation of the gas, grows calmer under its influence, while a normal pulse usually become slightly stronger and more frequent, and so remains until the termination of the anæsthetic process. As the narcosis deepens the respirations, which were at first slow and reluctant, become under the stimulus of insufficient oxygenation more rapid; the eyelids and the muscles of the face twitch convulsively; the eyeballs protrude; the lips assume a livid hue, and the entire face becomes first pallid, and then cyanosed, in which latter condition the whole cutaneous surface participates, the discoloration being easily observed around and under the finger-nails and other more delicate and vascular portions of the integument. The aspect of the patient is at this time ghastly in the extreme, there being every physical indication of impending asphyxia, the gravity of the symptoms being intensified by the stertorous character which at this point the respiration generally assumes. These appearances are coincident with an anæsthesia sufficiently profound for the needs of minor surgery, and the inhaler must be withdrawn and the operation swiftly performed.

It will be observed that while the third stage, or the stage of full anæsthesia, has been reached, it has not at the time indicated for the operation been so fully developed as is requisite for safety in operations under ether or chlorofrom narcosis, the most notable point of difference being that when the latter agents are employed complete relaxation of the whole voluntary muscular system must be attained, while nitrous oxide, as ordinarily used, cannot be safely pushed beyond a point in which the general muscular system is still unrelaxed, the only exception being in the muscles of the tongue, to whose more or less complete paralysis, and the consequent contact of the organ with the vibrating velum, the snoring respiration of the patient is due. Were the administration of the gas pushed farther, complete muscular relaxation and a more profound anæsthesia would follow; but this result cannot be safely produced with this agent except under conditions to be presently described.[1]

The hemorrhage following an operation under nitrous oxide, given undiluted, is always more or less venous in character—a result due to the exclusion of oxygen from the respiratory tract. The venous hue is very noticeable in the bleeding following the extraction of a tooth: not only is the blood dark in color, but, owing to contraction of the arterioles, sluggish in outflow.

Time Required.—The average time required to anæsthetize a patient with nitrous oxide is rather less than a minute (Thomas), or, according to the observation of Mr. Charles James Fox, from fifty to one hundred seconds.

Amount of Gas Required.—The amount of gas usually required to produce satisfactory anæsthesia in an adult is from five to six gallons. Of this quantity, according to the careful measurements of Dr. Evans of Paris, there remains in solution in the blood at the time of full anæsthesia an average of three quarts. M. Paul Bert, a later observer, finds that one hundred volumes of blood hold in solution forty-five volumes of gas when anæsthesia is complete.

Expiratory Products.—The products of the expiratory movements which take place during the administration of the gas are found to consist of the residuum of atmospheric air remaining in the lungs at the beginning of the process, *unchanged* nitrous oxide, watery vapor, and carbonic acid gas. The amount of the latter gas exhaled is often almost 50 per cent. less than during normal respiration—a result doubtless due to the partial suspension of the process of combustion through the insufficient supply of oxygen to the tissues.

MM. Jolyet and Blanche report some carefully conducted experiments made with a view to ascertaining the changes produced in the gases held in solution in the blood by the inhalation of nitrous oxide.[2] A dog after breathing pure air was found to have in one hundred cubic centimeters of blood the following percentage of gases:

Carbonic acid	48.8 per cent.
Oxygen	21 " "
Nitrogen	2 " "

The dog was then made to breathe within a bag a gaseous mixture consisting of—

Nitrous oxide	62 per cent.
Oxygen	24 " "
Nitrogen	17 " "

In seven minutes and thirty seconds the animal inhaled 50 liters of this mixture, and during all that time remained sensible to the touching of

[1] See method of M. Paul Bert, p. 170.

[2] *Archives de Physiologie*, tome cinquième, 1873.

the eye and pinching of the toes. The analysis of the gases in the blood then made gave for 100 cubic centimeters of arterial blood, quite red—

Carbonic acid gas	46	per cent.
Oxygen	19.7	" "
Nitrous oxide	29	" "
Nitrogen	0.3	" "

The same animal, having been allowed to rest during half an hour, was made to breathe pure nitrous oxide during one minute forty-five seconds: the animal was incommoded in his respiration, but retained sensibility. An analysis of the gases in the blackened arterial blood was then made, and it was found to contain—

Carbonic acid gas	37	per cent.
Oxygen	5.2	" "
Nitrous oxide	28.1	" "
Nitrogen	0.7	" "

A second dog, breathing in the same manner within a bag of nitrous oxide, was found insensible to pinching and to contact with the conjunctiva after three minutes. The analysis of the gases of the blood then made gave for 100 cubic centimeters of very black arterial blood—

Carbonic acid gas	36.6	per cent.
Oxygen	3.3	" "
Nitrous oxide	34.6	" "

A third dog, breathing within a bag of nitrous oxide, was still a little sensible at the third minute, and was found completely insensible to the electrization of the sciatic nerve after four minutes. The analysis of the arterial blood, very black, gave—

Carbonic acid gas	34	per cent.
Oxygen	0.05	" "
Nitrous oxide	37	" "

Return to Consciousness.—The recovery of the patient from the effect of nitrous oxide is usually very rapid and unattended by unpleasant symptoms. In females of a nervous temperament hysterical manifestations are occasionally developed, but these usually disappear as the gas becomes fully eliminated from the circulation, and nervous tremors, slight convulsions, moans, or piercing shrieks need excite no particular alarm; indeed, the louder the outcry the more assured is the safety of the patient, as it indicates a vigor of lung-power and a rapidity of respiratory changes in the highest degree salutary and assuring. The restoration to consciousness is attended by subjective sensations varying greatly in character: as a rule, these sensations are not very agreeable; often they are intensely painful, especially when the operation has been severe or unduly prolonged; but not infrequently the patient awakes as from a delightful dream, having known neither pain nor discomfort throughout the entire process. The recovery of consciousness is usually attended by the same dizziness and ringing in the ears which preceded its loss; the tinnitus aurium sometimes becomes a crescendo movement ending in a deafening roar like the rush of an approaching express-train. As the blood becomes again oxygenated the normal appearance of the patient is restored, and usually all the functions resume their wonted activity.

Resuscitatory Measures.—Signs of danger, when they occur, are usually connected with the respiratory function: intensified lividity of the face or great and sudden pallor, deepening stertor, cessation of respiration,—all are grave symptoms, and demand prompt remedial measures. In dental practice, to which the use of nitrous oxide is so largely confined, it will be found that the most prompt and generally efficacious resuscitatory measure is to draw the patient directly forward from the chair, supporting him in a nearly horizontal position face downward, thus favoring the removal of any obstruction caused by the tongue: the operator may at the same time stimulate the respiratory reflexes by thrusting the finger into the fauces. In a vast majority of cases these simple measures will avail, but should evidences of respiratory or cardiac arrest continue, such symptoms must be met by prompt recourse to those other methods for the resuscitation of patients thus perilously circumstanced already fully described in that portion of this paper devoted to the consideration of the properties and uses of sulphuric ether.

NATURE OF NITROUS OXIDE NARCOSIS.—The most superficial observer of the physiological effects of undiluted nitrous oxide cannot fail to note the fact that a more or less complete asphyxia is one of the leading symptoms produced. Many have over-hastily arrived at the conclusion that asphyxia pure and simple is the essential element, and, indeed, the sole factor in anæsthesia with this agent. This conclusion, however, is not well founded, as the simple asphyxia produced by mechanical means or by the inhalation of inert gases, such as hydrogen and nitrogen, differs greatly from that incident to narcosis from nitrous oxide.

Even more erroneous is the view, once urged with considerable insistence by various writers upon the subject, that anæsthesia with nitrous oxide is a condition of hyperoxygenation resulting from the decomposition of the nitrous oxide in the circulation. The fallacy of this position is manifest from the fact that a much higher temperature than that at which animal life is possible is necessary to effect any rapid decomposition of the gas, and that nitrous oxide when inhaled comes off from the lungs unchanged.

The experiments of MM. F. Jolyet and T. Blanche show that the germination of seeds and the growth of plants are arrested in pure nitrous oxide, and that the gas is not able to support respiration in animal any more than in vegetable life. The manner of conducting these researches is thus described by the experimenters:[1]

"We placed under bell-glasses containing nitrous oxide, chemically pure, grains of barley and water-cress in contact with moist filtering-paper. We have demonstrated that after nine days in one case and fifteen in another the seeds did not present the slightest indication of germination, while other barley and water-cress seeds arranged in the same manner, but under a bell-glass filled with atmospheric air, had entered upon full germination by the second or third day.

[1] *Comptes rendus*, séance du Lundi, Juillet, 1873, pp. 59-61.

"The seeds placed in nitrous oxide germinated in their turn when a few centimeters of oxygen were passed under the bell-glasses.

"The same results were obtained with seeds in course of development: the development was arrested in an atmosphere of nitrous oxide, and resumed when oxygen was placed beneath the bell-glass. . . . .

"Birds" (in nitrous oxide) "die in thirty seconds; the mammifers (rabbits and dogs), in from three to four and a half minutes. At death the blood is black in the vessels; the autopsy presents the ordinary signs of asphyxia by inert gases, nitrogen and hydrogen.

"We have made dogs breathe a mixture of nitrous oxide and oxygen in the relative proportions of atmospheric air during from twenty to thirty minutes without having been able to discover at any time any appreciable diminution of sensibility: the sciatic nerve, excited by a feeble galvanic current, has always produced signs of acute pain.

"These experiments are sufficient to show that nitrous oxide gas is not a true anæsthetic agent, and that it produces insensibility only by causing asphyxia."

This conclusion, based upon insufficient data, more recent investigation has completely nullified, and no fact is more clearly ascertained than that nitrous oxide, like chloroform and ether, does possess specific anæsthetic power, the asphyxia being merely incidental and entirely dependent upon the manner in which the gas is administered. Like the vapor of the liquid anæsthetics, nitrous oxide is simply held in solution in the blood, and from thence exercises its peculiar influence upon the nervous system.

What, in its final analysis, the nature of this influence really is, is still undetermined. Claude Bernard, C. Binz, and Heinrich Ranke have each advanced the doctrine that anæsthetics in general produce in nervous protoplasm molecular changes closely allied to, if not identical with, coagulation ("semi-coagulation of the intimate constituents of the nervous-cells"—Bernard), this resulting in temporary arrest of functional power. As this arrest is only transient, the resolution and revitalization of the coagulated albumen must be assumed.

That this sequence of changes is possible would seem to be indicated by the fact that the albumen of serum coagulated by alcohol redissolves if quickly placed in water, but if allowed to remain for some time exposed to the action of the alcohol, it becomes permanent and insoluble (Brunton).

Whether coagulation of protoplasm be the causative agent or not, there is no doubt that arrest of molecular movement in those centres in which nervous force is generated is a determining condition of narcosis, and that such arrest is the result of the interference of the narcotic agent with that tissue oxidation upon which all vital phenomena are dependent. Whether this interference is effected through the mechanism of coagulation is still an open question. The theory of Lyman is that the narcotic "effects no new combinations or decompositions. Among the molecules it merely plays the part of a cloud between the sun and the earth, hindering the energies of the one from acting upon the susceptible matter of the other."

Experiments of Paul Bert.—Much light has been thrown upon the true nature of nitrous oxide narcosis by the experiments of the late Prof. Paul Bert, who by administering under increased atmospheric pressure a mixture of oxygen and nitrous oxide succeeded in producing a prolonged and profound anæsthesia, while at the same time maintaining the normal proportion of oxygen in the blood. This mixture of oxygen and nitrous oxide had repeatedly been tested before Paul Bert's experiments, but with unsatisfactory results, because under normal pressure even a small amount of oxygen was found to dilute the nitrous oxide—that is, widen the distance between its molecules too much to permit of its full physiological effects being produced.

Laws of Dosage.—In giving any drug with a view to the full development of its physiological action the laws of dosage must be observed: a given amount, ascertained by experiment, must be administered in a given time. If the amount be diminished, either absolutely, or relatively as to time by unduly extending the period occupied in its administration, diminution in potency of effect must result.

In the exhibition of remedies hypodermically or by the stomach the laws of dosage are, as a rule, readily ascertained and observed, but in the administration by the lungs of an aëriform substance, such as nitrous oxide, the volatile nature of the agent and the physical obstacles to its retention in contact with absorptive surfaces complicate the problem: a much larger amount must be inhaled than can be absorbed, because repeated respiratory acts are necessary in order to bring fresh supplies of gas in contact with those finer ramifications of the air-passages from which it diffuses into the blood with the greatest rapidity; a large percentage of the gas inhaled fails to reach these surfaces, but remains in the larger bronchial tubes, where absorption is both absolutely and, as to volume, relatively slower, and whence much of it is driven out and lost at each expiration.

Practical experience has shown that in order to develop the full physiological effects of nitrous oxide at normal pressure, from five to seven gallons of pure gas must enter the lungs in about a minute of time. To materially diminish the amount of the gas, or to subdivide it into several doses with a considerable interval of time between each dose, would alike defeat the purpose of its administration, just as the dividing the physiological dose of morphia, one-sixth of a grain, into one hundred and sixty-eight parts, and giving one part every hour for a week, would be an utterly futile procedure were pronounced physiological effects desired, the reason of failure in each case being that a sufficient number of the molecules of the agent employed have not been brought in contact with absorptive surfaces within a sufficiently limited period of time, the result being that the molecules first absorbed are eliminated from the system before additional molecules can come to their aid, defeat in detail being the necessary consequence.

This result has been found to follow all dilutions of nitrous oxide at normal atmospheric pressure; but if the molecules of nitrous oxide, diluted—that is, driven more widely asunder—by the interposition of molecules of oxygen, can again be driven together, so that they and the oxygen shall occupy only the bulk filled by the nitrous oxide alone before the addition of the oxygen, then when inhaled the same number of nitrous oxide molecules will enter the lungs at each inspiration as before dilution, and room still be left for the molecules of oxygen.

Compression of Nitrous Oxide.—The compression of the gas or gases is of course readily accomplished, but in order to secure successful anæsthetic results the patient also must be placed under the same atmospheric pressure as that at which the anæsthetic mixture is held, so that the pressure of the gases as they enter the lungs may be exactly counterbalanced by the pressure of the air upon the walls of the chest. This result, except under peculiar conditions, it is impossible to obtain in the open air. Dr. Fontaine[1] has pointed out that in very deep mines atmospheric pressure is so much greater than at the surface of the globe, as is notably the case in two mines in England, in which the barometer marks 90 and 92 centimeters respectively (76 normal), that, should a surgical operation in those depths become necessary, nitrous oxide diluted with a limited amount of oxygen might be employed without any special apparatus; but at ordinary levels some such appliances as those employed by Prof. Bert are absolutely necessary. M. Bert's invention was first publicly announced in a communication to the French Academy,[2] in which he says:

"Nitrous oxide, the anæsthetic properties of which were discovered by Humphry Davy at the end of the last century, is to-day employed by a very large number of practitioners to obtain insensibility during the extraction of teeth. But that insensibility cannot be prolonged, for the reason that at the moment in which it is complete signs of asphyxia appear, which speedily become formidable. American surgeons have not yet succeeded in performing prolonged operations under nitrous oxide, except by producing brief anæsthetic sleeps frequently repeated, but separated by periods of sensibility.

"This disability is due to the fact that anæsthesia with this agent cannot be produced unless the patient is made to breathe pure nitrous oxide without any admixture with air, the result being that asphyxia keeps equal pace with anæsthesia.

"I have attempted to remedy this serious disadvantage, and have succeeded in obtaining an anæsthesia indefinitely prolonged, and at the same time absolutely free from all danger of asphyxia.

"The fact that nitrous oxide must be administered pure signifies that in order that a sufficient quantity may penetrate the organism the tension of the gas should be equal to one atmosphere. Under normal atmospheric pressure it is necessary in order to secure this result that the gas should be inhaled in the proportion of one hundred volumes in one hundred. But if we suppose the patient placed in an apparatus where the pressure may be raised to two atmospheres, it would be possible to give the gas at the desired tension by making him inhale a mixture consisting of fifty parts nitrous oxide and fifty parts of atmospheric air; thus anæsthesia should be obtained while at the same time maintaining the normal quantity of oxygen in the blood, and so conserving the normal conditions of respiration.

"This result has been obtained, but it should be stated that as yet I have experimented only upon animals. These experiments have been performed as follows: I enter the cylinder, and, increasing the atmospheric pressure

[1] *L'Union Médicale*, Sept. 18, 1879.

[2] *Comptes rendus des Séances de l'Académie des Sciences*, séances du Lundi, 11 Novembre, 1878.

one-fifth above the normal, there cause a dog to inhale a mixture consisting of five-sixths nitrous oxide and one-fifth oxygen gas—a mixture in which it will be seen that the tension of the so-called laughing gas is precisely equal to one atmosphere. Under these conditions the animal is in one or two minutes, after a very brief period of excitement, completely anæsthetized; the cornea or conjunctiva may be touched without making the eye wink; the pupil is dilated; a nerve of sensation may be exposed and pinched, a limb may be amputated, without causing the slightest movement. The muscular relaxation is truly extraordinary, and were it not that the respiratory movements continue with perfect regularity, the animal would appear stricken with death. This condition may continue half an hour or an hour without any change. During all this time the blood preserves its red color and its normal amount of oxygen, the heart pulsates with its usual force and regularity, and the temperature continues unchanged. During this entire period the excitation of a centripetal nerve produces in the respiratory and circulatory functions all the usual reflex manifestations; all the phenomena of the so-called vegetative life remain unchanged, while those peculiar to animal life are absolutely abolished.

"When, after whatever period of time, the bag containing the mixture of gases is removed, the animal at the third or fourth respiration of pure air will immediately recover sensation and intelligence, as proved by his desire to bite, which sometimes he manifests immediately. When unloosed he hurries away, walking freely and recovering at once his gayety and vivacity.

"The rapid return to the normal condition, so different from that which is observed with chloroform, is due to the fact that nitrous oxide does not, like chloroform, enter into chemical combinations in the organism, but is simply dissolved in the blood. As soon as the gas is no longer contained in the air inhaled it rapidly escapes through the lungs, as analyses of the gases in the blood have shown me.

"The innocuousness of the action of nitrous oxide is shown from the recital of these experiences. On the one hand, in fact, the anæsthesia, in striking down the sensibility of the spinal cord, respects the reflexes of organic life, the suppression of which, readily effected by chloroform, can alone put life in jeopardy; on the other hand, the immediate return to the normal state when the patient is again brought into free air makes the operator at all times master of the situation.

"This freedom from danger is shown not less clearly from the infinitely small number of accidents which have followed the inhalations (numbered by hundreds of thousands) effected at the hands of dentists, often with a total disregard of prudence and a total absence of competency, and under conditions in which asphyxia augments the dangers, if any exist, of anæsthesia with this agent.

"I am therefore now authorized by the result of my experiments made upon animals to earnestly recommend to surgeons the employment of nitrous oxide under pressure, with a view to obtaining an anæsthesia of long duration. I can assure them that they will obtain, in proportioning as I have indicated the barometric pressure and the centesimal composition of the mélange, so as to have, for the nitrous oxide, the tension of one atmosphere, and for the oxygen at least the normal tension of the air, an insensibility and a muscular relaxation as complete as they will desire, followed by an immediate return of sensation and condition of general well-being perfect in character."

A few months subsequently M. Bert addressed to the Academy a communication in which he announced the successful employment of his method upon the human subject, and gave the following account of the first operation performed:[1]

"Two surgeons of the hospital of Paris have responded to the appeal which I addressed to surgical practitioners, and I now give to the Academy an account of the operations which they have performed after the new method. As a typical case I will first describe the first operation, which was performed by M. Labbé.

"The operation required was the extirpation of an ingrowing nail, with removal of the matrix. The patient was a young girl twenty years of age, very timid and nervous. We entered the large sheet-iron chamber in the establishment of Dr. Daupley, where the pressure of the air was in a few minutes augmented by $0^{m}.17$ (total pressure, $0^{m}.92$). The patient placed herself at full length upon a mattress, and M. Préterre applied to her mouth and nose the valved mouthpiece which he is accustomed to employ for the inhalation of pure nitrous oxide; then the sack with which it communicates was filled with a mixture containing eighty-five parts of nitrous oxide and fifteen parts of oxygen. I held one of the arms of the patient and found the pulse quite rapid, when suddenly, without having been warned by any change in the pulse, the respiration, or the color of the skin, without any rigidity, agitation, or excitation having been produced, in from ten to fifteen seconds after the first inspiration of the anæsthetic gas, I felt the arm become completely enfeebled; insensibility and muscular relaxation were obtained; even the cornea could be touched with impunity. The operation began immediately, and the dressing of the wound followed without a single movement of the patient, who remained in a calm sleep; the pulse had returned to the normal rate. At the end of about four minutes, at the moment when M. Labbé had finished dressing the wound, slight muscular contraction in an arm, and then in a leg, was perceived. The operation having been completed, the mouthpiece was removed and the contractions immediately ceased. During thirty seconds the patient continued to sleep; then, some one having tapped her upon the shoulder, she awoke, regarded us with an air of astonishment, sat up, and suddenly cried that her foot was hurting her; indeed, the pain was sufficient to cause her during a few seconds to shed tears. Being interrogated, she declared that she felt perfectly well and was very hungry, as, owing to fright, she had neither breakfasted in the morning nor dined in the evening. She declared further that she had felt nothing, dreamed nothing, but she recalled that at the first inhalations of the mixture she experienced a feeling of great well-being, that she appeared to be mounting to heaven, and that she 'saw the blue sky with the stars.' This being said, she arose and went on foot to the vehicle which was to convey her to the hospital; but on the way she complained so much of hunger that it was necessary to stop in order to obtain for her something to eat. No ill consequences of any kind have resulted from the operation.

"I have given in some detail the history of this first operation, because it exhibits very clearly the great difference between the action of nitrous oxide and that of ether or of chloroform, especially as regards the instantaneousness of the sleep and the awakening. But the operations performed at the establishment of Dr. Fontaine—operations which are now sixteen in number—have been much more important, and as a consequence much more conclusive. They comprise three amputations of the breast, four

[1] *Comptes rendus*, séance du Lundi, 21 Juillet, 1879.

operations upon the bones, six extirpations of different varieties of tumors, a resection of the infraorbital nerve, and two reductions of shoulder dislocation of three or four days' standing. The duration of the anæsthesia has varied from four to twenty-six minutes. Insensibility has been complete during a period varying from fifteen seconds to two minutes. During one of the operations a slight accident to the apparatus permitted to the patient one respiration of the exterior air: she immediately began to speak, but without any manifestation of pain; at the first renewed inspiration of the anæsthetic mixture speech was arrested, and upon awakening she recalled nothing of what had happened.

"The pulse and respiration are sometimes accelerated at the beginning of the inhalation, and it is not yet possible to determine to what extent these phenomena are due to the action of the gas. As soon as the patient becomes insensible the normal rate is restored. In a great majority of cases the patients issue from the apparatus without complaint of any disagreeable sensations of any kind: when the operation has not been grave they depart on foot, and frequently ask for something to eat. In three cases nausea has been complained of; but as these cases were precisely coincident with the employment of hard-rubber mouthpieces and gas-bags made of new rubber, it is impossible to determine whether the nausea should or should not be attributed to the nitrous oxide: my own opinion is that it should not.

"A symptom more frequent, and which might appear sufficiently grave, is the appearance of muscular contractions in the limbs. I am sure that they are due to the fact that the nitrous oxide is not under a sufficient tension. In order to quiet the spasmodic action, it is only necessary to make the pressure in the pneumatic chamber from $0^{m}.02$ to $0^{m}.03$ greater; and this can be effected almost instantaneously. The pressure employed has oscillated between $0^{m}.15$ and $0^{m}.22$ above the normal. . . . . Thus the employment of compressed air permits with the greatest facility the modification of dosage in pneumatic therapeutics. Nothing would be more difficult than to change the proportions of a mixture of gases: nothing is more simple than to vary the tension, and as a consequence the physiological dose.

"To sum up: Nitrous oxide enters the domain of major surgery. The previsions of my communication of November 11 have been realized. It has shown its superiority over the hydrocarbon and chlorine compounds—1st, by the absence of that period of initial excitation often so distressing and at times even dangerous; 2d, by the security it affords the surgeon, who, assured that the dosage of the anæsthetic agent cannot change during the operation, knows, as a consequence, that the patient has nothing to fear; 3d, by the return, almost instantaneous, even after twenty-six minutes of anæsthesia, to complete sensibility, so that it would be quite possible, were it desired, to awaken the patient at any time during the operation and immediately put him to sleep again; 4th, by the almost invariable absence of malaise, nausea, and vomiting, so frequent, so exhausting, and sometimes so persistent, in cases where the patient has been placed under the influence of chloroform or ether; 5th, by its remarkable freedom from danger, the reasons for which have already been explained in my first communication, and have since then been confirmed by experiments upon the human subject.

"I do not believe that the mechanical difficulties attending this method—difficulties which have been greatly diminished by the introduction of a movable pneumatic chamber by Dr. Fontaine—will deter surgeons from its use; but it is my duty to-day to thank Drs. Labbé and Péan, whose bold initiative, justified by the result of my previous experiments, has allowed nitrous oxide to pass from the laboratory of the physiologist to the operating-room of the surgeon."

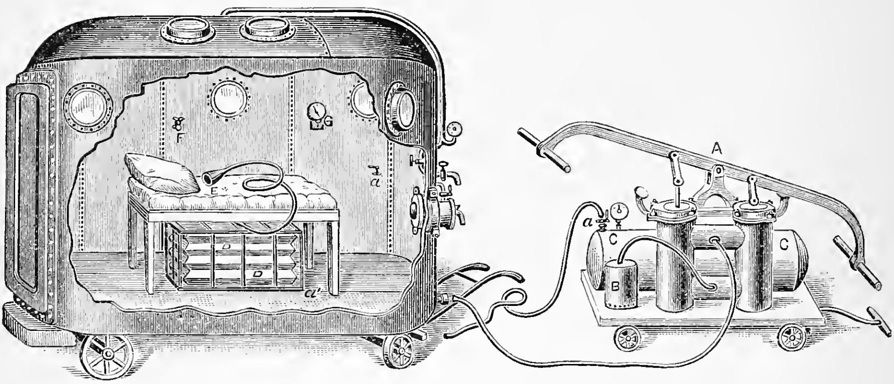
The pneumatic chamber above mentioned is thus described by Dr. Fontaine:[1] (Fig. 27.)

"This apparatus, mounted upon a truck, is painted white on the inside. It is lighted by ten portholes, of which the four upper ones shine directly upon the operating-table. The width of the chamber is two meters (a little over six feet and a half), its length three meters and a half (about eleven feet and a half), its height two meters and sixty-five hundredths (a little more than eight feet and a half). It will comfortably accommodate ten or twelve persons.

"The receiver in which M. Péan has operated during the last three months, and into which he took with him five or six assistants, had not one-third the available space that has the apparatus just described. The pressure can be regulated at will, either from the interior or the exterior. In either case a metallic manometer serves as a guide.

"By the side of the pneumatic chamber, upon a little truck, are placed —1st, a double-cylindered hand-pump, A, with liquid piston, capable of

Fig. 27.



giving from four hundred to six hundred liters of air per minute. 2d, a refrigerator, B, placed in the path of the air from the pump, in order to prevent the temperature of the pneumatic chamber from rising more than one or two degrees above that of the surrounding air. During the winter the refrigerator can be replaced by a heating apparatus consisting of a hot-water bath surrounding a coiled pipe, through which the air may pass. 3d, an iron receiver, C, containing three hundred and fifty liters of the anæsthetic gaseous mixture at a pressure of ten atmospheres (about three and a half cubic meters at the ordinary atmospheric pressure).

"Upon the inside of the pneumatic chamber are seen two keys, *a* and F, of which the first operates a stopcock which communicates with the

[1] "Emploi chirurgical de l'Air comprimé." *L'Union Médicale*, Sept. 18, 1879, p. 445. See also *De l'Anesthésie par le Protoxyde d'Azote d'après la méthode de M. le Professeur Paul Bert*, par Raphaël Blanchard, Docteur en médecine, etc.

receiver, C, containing the anæsthetic mixture under pressure, and with the gas-bag, D, placed under the operating-table. When this bag is nearly empty it can be filled by connecting the stopcocks with the rubber tubing which forms the supply-pipe. The second key, F, belongs to a whistle used to signal to those who operate the pump.

"At the letter E in the figure is seen the facepiece of the inhaling apparatus."

Paul Bert's Method in Dentistry.—Dr. E. Goetz, in a paper read before the Medical Society of Geneva, December 5, 1883, states that two dentists in that city, M. Roussy and M. Guillermin, have placed in their offices apparatus for giving nitrous oxide gas after Paul Bert's method. The pneumatic chamber used by the former has a capacity of fifty-eight hundred liters and will hold four persons very comfortably.

"It contains an arm-chair and a table, under which is placed a rubber bag capable of holding one hundred and fifty liters of the mixture of nitrous oxide and oxygen—a quantity sufficient to maintain anæsthesia for about fifteen minutes. All the instruments, as well as the water, towels, and napkins necessary for the operation, are put into the pneumatic chamber: if by chance the operator has forgotten anything or has need of another instrument, he can readily obtain it by means of an opening with double doors through which anything he may wish can be passed without changing the tension of the condensed air.

"The compression of the air is effected by means of an hydraulic motor of two horse-power placed in the basement. This puts in action an air-pump, suction and forcing, which conveys the air into the pneumatic chamber by means of perfectly-jointed metallic pipes. In order that time may not be lost in waiting for a sufficient tension in the chamber, M. Roussy has placed near by a reservoir of sheet iron in which eighteen hundred liters of compressed air may be stored at a pressure of one atmosphere and a half. During each anæsthetic *séance* a mechanician should be placed near the apparatus to obey the electric signals transmitted by the operator.

"To secure a pressure of twenty-five centimeters with the pump alone requires nine minutes; seven minutes are sufficient when the air has been compressed in advance in the reservoir just spoken of.

"The first twenty experiments were made with the mixture of gases recommended by Paul Bert—fifteen parts of oxygen to eighty-five parts of nitrous oxide, with a pressure of from twenty-five to twenty-eight centimeters. For later operations the proportion has been twelve of oxygen to eighty-eight of nitrous oxide: anæsthesia with this combination has appeared to be produced more rapidly and to be of longer duration.

"With this explanation it is easy to comprehend the function of the apparatus. The patient and the operator, accompanied by one or two assistants, enter the pneumatic chamber: the door is closed and all communication with the outer air is arrested. The cock communicating with the reservoir is opened; immediately the compressed air enters the chamber, causing the manometer to rapidly rise ten centimeters. Then the signal is given to the mechanician to put the pump in movement; each stroke of the piston is distinctly heard in the chamber. The first impression experienced is not very agreeable: one feels a painful sensation in the ears, produced by the inequality of tension between the middle ear and the external wall of the tympanum. To overcome this difficulty, maintained by a slight mucous obstruction of the Eustachian tube, all that is necessary is to go through the movements of deglutition several times: the vacuum produced in the pharynx by these movements draws out the air retained in the drum of the ear and re-establishes the permeability of the tube. If the obstruction resists these means, all that is necessary is to turn the stopcock, placing the chamber in communication with the exterior air: the tension will be lowered two or three centimeters and the normal condition of things will be restored. This is the sole inconvenience which we have experienced, and even that is not of invariable occurrence. In one case, however, the pain felt by one of the assistants, a physician of our city, was such that it was necessary to momentarily suspend the pressure and increase it only very slowly. This is the only case we have observed, and I have not found other examples of a like nature in the published reports of MM. Blanchard and Martin.

"I have, in all my observations, counted the pulse and the respiration before the compression of the air and at the moment in which it attained its maximum: I have not found any notable difference, but usually a little acceleration of the pulse. It need hardly be said that these observations were made either upon myself or an assistant, for the patient, agitated by the thought of the operation to which he is about to submit, presents almost always an acceleration of the pulse, which increases as the moment approaches.

"At the end of nine or ten minutes the tension in the pneumatic chamber is sufficient: the manometer marks twenty-five centimeters and the barometer one hundred centimeters or a little more. The administration of the anæsthetic is then begun: the mask is applied to the face of the patient and the communication with the sack containing the anæsthetic mixture is opened. After ten or fifteen inspirations, often after only six or eight, anæsthesia is complete, without excitation, without change of color either in the skin or mucous membrane, and without modification in the respiratory rhythm. The limbs become relaxed, the conjunctiva is insensible, the pupil slightly dilated. The muscles of the jaw alone retain contractile power, and this even in a somewhat exaggerated form, so that it is well to place a prop in the mouth before the commencement of inhalation. When the anæsthesia is deemed sufficient the operation may be performed without any very great haste; indeed, with the method of Paul Bert applied to the extraction of the teeth, in which it is necessary to remove the mask, the time afforded the operator is very much longer than by the ordinary method without compression: we have always obtained, and with moderate pressure, a minute or a minute and a quarter of absolute anæsthesia, often followed by a period of analgesia sufficiently perfect to prevent suffering even though the patient is conscious that his teeth are being extracted. In order to obtain a more prolonged anæsthesia it is only necessary to give the patient a little more of the anæsthetic or to increase the atmospheric pressure a few centimeters, which can be done without the slightest inconvenience.

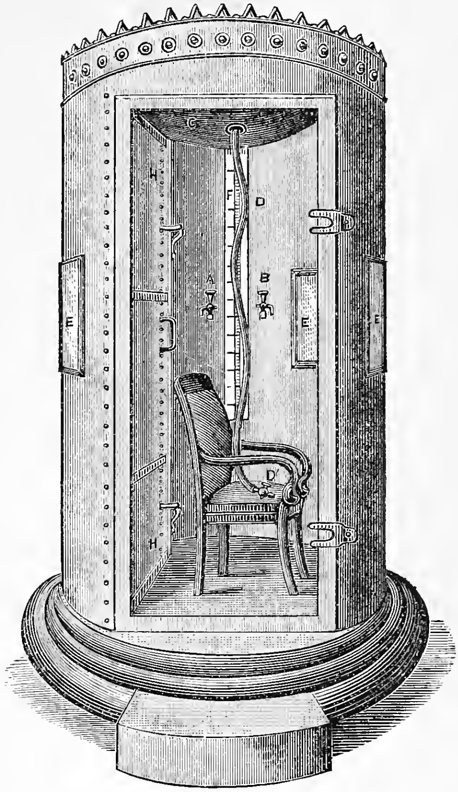
"The operation being terminated, the patient recovers consciousness almost immediately, and has no subsequent feeling of malaise.

"The stopcock which permits the escape of the compressed air is then opened and little by little the tension becomes normal."

Fig. 28 represents the pneumatic chamber employed by M. Guillermin of Geneva, who gives the following description of its mechanism:

"It is sufficient to state that the apparatus is provided with a pump to compress the atmospheric air into a large special reservoir. This reservoir communicates with the key A (Fig. 28) of the pneumatic chamber by a pipe. There is also connected with the apparatus a pump for the compression of the mixture of nitrous oxide and oxygen into a smaller reservoir, which is in communication with the sac CC. These need not here be further described. We will enter more into detail concerning the principal apparatus, the pneumatic chamber:

Fig. 28.



"It is constructed absolutely upon the same principle as that which was used in operations in major surgery in Paris: it differs only in that its dimensions are smaller and in some interior arrangements designed to make easier its operation. It is a round chamber made of steel plate, measuring 2.20 meters (a little over six feet) in height by 1.20 meters (a little more than three feet) in diameter. It is closed by a door, HH, also of steel plate, opening from without to within, and the edges of which have upon their entire length a band of rubber, assuring the hermetical closure of the cabinet. Articulated bolts fixed to the door enter into grooves welded to the walls of the chamber, and are firmly screwed by a nut-wrench. The light is introduced by four portholes or windows, E, E, E. The sack, CC, contains the mixed gases, the proportions of which are calculated by the means of a 'Limousin' reckoner, which gives even the deciliters. The sack has two openings—a large one for the gas to enter, and the other smaller, from which hangs the pipe D, terminated by the inhaler, D′, that is seen lying on the operating-chair. The operator manages the apparatus easily. The door closed and the patient seated, the stopcock A (entrance of the compressed air) is opened; the pressure of the air is produced at once; the column of mercury is seen to mount in the barometer, F. The inhaler, D′, is placed over the face of the patient, who rapidly passes into a calm and profound sleep. When the operation is done the stopcock, B, is opened, and in two or three minutes the reduction of pressure is complete and the column of mercury resumes its normal state. The door is opened from the outside, and the patient, who is well immediately and without malaise of any kind, is able to go out: all is finished."

Concerning the utility of the apparatus, M. Guillermin states that—

"Operations upon parts of the face covered by the inhaler are also very easily performed by the method of Paul Bert, by supersaturating the patient (which can be done with absolute harmlessness). A large quantity of the gas accumulates in the blood, and while the gas escapes by the lungs the insensibility remains several minutes after the inhaler is removed. Many consecutive extractions of teeth can be made.

"Dr. Péan and other surgeons are able to use this same principle to perform different operations upon the lips (ablation of cancroids and epitheliomas), resection of the superior maxillary nerve, etc. This *supersaturation* cannot be effected with pure nitrous oxide without imminent danger of asphyxia."[1]

Dr. Goetz states that in addition to the pneumatic apparatus of M. Fontaine in Paris, previously described, and those of MM. Roussy and Guillermin in Geneva, a pneumatic chamber has been constructed for M. Martin at Lyons, in which Prof. Gayet has performed an iridectomy and an enucleation of the eye, and that Prof. Deroubaix of Brussels has placed a complete apparatus in St. John's Hospital, in which he has applied the method of Paul Bert with excellent results.

Nitrous Oxide and Oxygen at Normal Pressure.—Subsequent to the introduction of this process M. Bert demonstrated that prolonged anæsthesia may be safely obtained with nitrous oxide at normal pressure by giving first the gas in the pure form, and then a mixture of nitrous oxide and oxygen: thus the blood is first saturated with the anæsthetic gas and then oxygenated by the oxygen of the mixture, the nitrous oxide the latter contains serving at the same time to keep up, to a certain extent, the anæsthetic influence. When this ceases to be sufficiently profound the pure gas is again administered, followed in its turn by the mixture.

This procedure is not absolutely novel, as American specialists have frequently succeeded in keeping up anæsthetic influence for several minutes by giving alternate doses of pure nitrous oxide and atmospheric air. The oxygen mixture of M. Bert is, however, a decided improvement; but for obvious reasons the usefulness of this plan must in a great measure be restricted to operations other than in the mouth.

Nitrous Oxide and Oxygen in Obstetrical Practice.—Dr. Macan, in a paper read before the Obstetrical Society of Dublin, gave an account of the use of a combination of nitrous oxide and oxygen in labor, and "described the latest modification introduced by Dr. Kilkowitosch of St. Petersburg, who employed the gas mixed with 20 per cent. of oxygen. The quantity of this mixture inhaled in each case varied from two to ten cubic feet, but its use might be continued for an unlimited time, as it was capable of supporting life like atmospheric air, and was quite free from danger, the patient, though quite anæsthetic, never losing consciousness; neither did nausea, vomiting, or headache result from its employment. Again, the amount of intra-uterine pressure, as tested by the dynamometer, exerted during the pains was not in the least diminished, even when complete anæsthesia was pro-

[1] "Emploi du Protoxyde d'Azote sous Pression, par M. Guillermin, Médecin-dentiste à Genève," *Gazette Odontologique*, Avril, 1881.

duced, whilst chloroform and ether were well known to cause marked diminution in the frequency and fulness of uterine and abdominal contractions."[1]

SECONDARY EFFECTS RESULTING FROM NITROUS OXIDE NARCOSIS.—These effects are usually of trifling importance. Headache is not infrequent, and occasionally there is slight nervous prostration, continuing for some hours or even days. It is hardly to be supposed, however, that so grave an interference with the functional power of important nervous tracts is invariably attended by absolute immunity from injurious results more or less serious in character.

Probably few practitioners of experience have not heard from or of persons that they have never been well since taking the gas. Concerning this matter, Prof. Darby writes:

"I have long been of the opinion that nitrous oxide gas is not as harmless as it is generally believed to be. I never see a person under its influence that I do not ask myself the question, Can any agent that produces the effect and appearance which this does be safe or be taken without danger to the general health? Given as it is by careless and often inexperienced men, the gas, I doubt not, being frequently impure, the anæsthetic must have a degree of safety, otherwise the deaths would be numerous, but whether all who take it return to perfect health I must question.

"One lady said to me that she attributed all her ill health to this agent, she having enjoyed perfect health until she took the gas for the purpose of having teeth extracted.

"Another case has been reported to me of a lady who has 'never had a well day' since, three years before, she had taken nitrous oxide. Indeed, several persons have remarked to me that they have never been well since taking the gas.

"While these cases do not positively prove anything, they are nevertheless important factors in helping us to form an opinion as to the perfect safety of the agent."

The late Prof. George T. Barker held very pronounced views as to the harmfulness of nitrous oxide as an anæsthetic agent, this unfavorable opinion being largely based upon his own unfortunate personal experience, he having had a severe attack of pneumonia the day following his inhalation of the gas, from the secondary effects of which attack he never fully recovered.

While, in common with Prof. Darby and many others, the writer has frequently heard statements as to the permanently injurious results which in individual instances have followed the inhalation of nitrous oxide, it has not been easy to secure satisfactory data concerning such cases. The statements themselves have been vague, and very often the symptoms complained of obscure. In any case, the difficulty of establishing a true causative relation between the anæsthetic agent and the disease is sufficiently obvious: in the following three cases, however, indications of pathological effects followed so promptly the inhalation of the anæsthetic as to afford ample reason for the presumption that such a relation really existed. For details concerning the first of these

[1] *British Med. Journ.*, Feb. 4, 1882.

cases the writer is indebted to Prof. C. N. Peirce and to Drs. R. J. Rudderow and James J. Levick.

The first case is that of the late Dr. K——, a practising physician of Philadelphia, concerning whom Prof. Peirce writes:

"I went with him to Dr. —— to have some roots removed under the influence of gas. He was then a man weighing two hundred pounds, was in good health, but was readily fatigued by violent exercise; indeed, he would not attempt to walk rapidly. The roots were all extracted with one administration of gas and at the immediate time without any unusual circumstances. From the office of Dr. —— he went to his place of residence, distant but a few blocks, where he remained for some hours, feeling very much prostrated, his face having an ash color and his circulation not resuming its normal condition for some hours.

"Within a few days sugar was discovered in his urine—my own recollection is that it was within forty-eight hours—and within ninety days he had lost forty pounds in weight, which was never recovered. He at once placed himself on a diet of meat and eggs, and lived largely upon this kind of food for seven years. A whole chicken or a pound of meat and four eggs was but an ordinary meal for him.

"Although living a quiet life, he yet occasionally indulged in long walks, and on returning from one of these on a warm day, very much overheated, he very imprudently plunged into a bath of cold water, and, as he expressed it to me, he 'thought he was done for,' as he had a severe struggle for life. But, as above stated, he lived for seven years, a large portion of the time secreting an unusually large quantity of sugar for a case of the kind, and, after being confined to the house for a few months, died with heart disease. To show the tendency to heart disease in his family, I might state that his half-sister died within a year with much the same symptoms as those which attended the last few months of his illness."

Concerning the same case Dr. Rudderow writes:

"Dr. K—— was in perfect health prior to the spring of '75, when at that time—I think it was in May—he took the gas. I saw him about twenty minutes after he had left the dentist's. He came into the house complaining of a sensation as if some one had him by the throat and was choking him. His pulse was feeble, his face pale, and the angles of the mouth drawn. He had headache, but no sick stomach. Heart and lung sounds were good. He remained in that condition nearly all day. The next morning, on passing water, he noticed that there was blood. Some time after—within a week or ten days, I think it was—he discovered sugar in his urine. From that time his kidney trouble gradually grew worse, and heart complications followed, which finally resulted in death."

Dr. James J. Levick, his attending physician during his last illness, makes the following statement concerning the case: "I was first called to see Dr. K—— professionally December 19, 1881, and I attended him until the time of his death, March 27, 1882. When I first saw him he had general anasarca, with abdominal effusion, a dilated heart, and, if I remember aright, albumen in his urine. There was nothing unusual in his symptoms, and they were readily referable to the ordinary causes of heart and kidney disease."

Dr. Rudderow also reports a second case as follows: "The second case was a man whom I saw in February, 1879, and who two months prior to my attending him, according to his statement, went through much the same experience as Dr. K——, with the exception that from the day following his taking the gas he became almost blind. When I saw him he had albumen and casts in his urine, and on examining his eyes there were in the retina evidences of albuminoid retinitis. He stated that he was in perfect health up to the time of taking the gas; had never had anything the matter with him; had never had syphilis, and, indeed, was a perfect specimen of manhood, with the exception of his kidney trouble, Bright's disease, of which he ultimately died."

A third case is reported by Prof. Peirce, as follows: "Mr. P—— was a man in apparent good health, attending daily to his business, a good feeder, and fond of the pleasures of the table. In weight he was not much short of two hundred pounds. By my advice he went to Dr. —— and took the gas for the extraction of roots and teeth, which was successfully done with one administration. Within two days I saw him in his room on a couch. His statement to me was that on returning to consciousness he felt dizzy, and that this vertigo continued for some days. When the impression of his mouth was taken for an artificial denture he complained, as he sat in a chair in his bedroom, that his head was full and dizzy; his face was somewhat flushed. He informed me that his physician had discovered albumen in his urine. He lived for a little over a year, but was never able to do more than be helped into his carriage for a short ride. I have been informed that during the last few months of his life he suffered from sugar in his urine, but of the correctness of this I cannot learn definitely."

There is every probability that in all the above cases there were preexistent organic or functional derangements, possibly so slight in character as to be unobserved, and that the partial asphyxia produced by the inhalation of nitrous oxide intensified the symptoms and precipitated a crisis which otherwise might have been much longer deferred, or under proper care and treatment entirely avoided.

This opinion finds ample confirmation in the recently published observations of Dr. Laffont,[1] which observations have so important a bearing upon the subject under consideration that they are here reproduced:

"It is generally believed that the only danger from the use of nitrous oxide as an anæsthetic, according to the method of surgeon-dentists, consists in the danger of immediate asphyxia resulting from the absence of pure oxygen in the gas breathed during the inhalations.

"As the result of a conference upon anæsthesia that I have made in the present year (1885) at the Institut odontotechnique de la Rue de l'Abbaye, I have been in communication with a great number of surgeon-dentists who came to ask of me information and counsel upon the employment of

[1] "Contre-Indications aux Inhalations de Protoxyde d'Azote pur," par le Docteur M. Laffont, *Comptes rendus hébdomadaires des Séances de la Société de Biologie*, Dec. 4, 1885.

anæsthetics. I have profited by my relations with some of these gentlemen to learn if certain pathological conditions appearing at first view to have no relation to that method of producing insensibility, but still appearing after it, may not have as their point of departure or occasional cause that method of anæsthesia itself, however innocent it may appear.

"I was much the more interested in these researches as I had had under my care persons having had unfavorable symptoms following insensibility caused by inhaling pure nitrous oxide gas.

"The following are the observations furnished me by various surgeon-dentists; my own also are included:

"*First Case.*—Mrs. V——, aged thirty-five years, pregnant four months and a half, having had two living children born at the end of term, as the result of intolerable dental neuralgia, which did not yield to any anodyne, went to have extracted a tooth which appeared to be the cause of the neuralgia.

"Mrs. V—— was in good condition, had never vomited nor had symptoms of a nervous nature; she was, however, much afraid, and her physician recommended that she should take an anæsthetic in order to have the tooth extracted. The surgeon-dentist with an assistant began the inhalations.

"Mrs. V—— did not readily yield to the influence of the anæsthetic, but turned spasmodically and had contractions of the limbs. The inhalations, however, were continued, and at the end of a minute and a half, the patient being cyanosed, the tooth was extracted without pain.

"The patient awoke a little stupefied, and had a headache, but was without knowledge of what had happened.

"The dentist lost sight of Mrs. V—— for more than a year, when she returned to his office accompanied by her husband and requiring care for her teeth other than extraction. Mr. V—— entered the operating-room before his wife and begged that no allusion to the previous extraction of the tooth be made, because after the anæsthetic had been taken Mrs. V—— had been in a deplorable state of health, with daily nervous attacks—that she had had no appetite and frequently vomited, and finally, a month and a half after the operation, had a miscarriage, the fœtus being in a state of maceration, the death probably dating from the day of the operation, as after that day Mrs. V—— felt no movement of the fœtus.

"*Second Case.*—Miss M——, aged fourteen and a half years, having been for five months perfectly regular in her menstrual flow, presented herself at the office of another surgeon-dentist for the extraction of a molar attacked by caries. This young girl had the appearance of the most robust health: her menstrual period was not due for ten days.

"Anæsthesia was produced by inhalations of nitrous oxide, which produced unconsciousness very quickly, and in which the cyanosis was very marked. Two teeth were extracted without pain: the patient awoke promptly, although cyanosed. An appointment for the extraction of two other teeth was made for the fifth day after the cessation of the next menstrual flow. The second appointment, however, was not kept, and the dentist, going for information, learned that since taking the anæsthetic the young girl had become pale, had lost strength, ate nothing, had changed singularly, and had frequent attacks of hysteria. The physician feared a chlorosis of a grave character. Miss M—— had had no menstrual flow at the usual time.

"*Third Case.*—A young student, Mr. P——, aged nineteen years, went to the office of a well-known surgeon-dentist to have the roots of the large inferior second molar on the right side extracted. The young man desired to be anæsthetized, because he had had when young a nervous disorder, and he feared that the extraction of the roots would require so much time that it would provoke a new crisis. He breathed copiously of the gas under the inhaling mask, and at the tenth respiration he twisted and became convulsively insensible. The dentist prepared to pull out the roots quickly, but he perceived that the patient no longer breathed. He hastened with his assistant to produce artificial respiration. Soon the patient became conscious, but was at once attacked with epilepsy. After a necessary rest he left, promising to return for the operation, which was to be performed without an anæsthetic. After some days the dentist received a letter in which he indefinitely postponed the operation, as since the administration of the anæsthetic the young student had been taken at the same hour each day with an attack of epilepsy.

"*Fourth Case.*—One of my patients, aged fifty-four years, suffering from diabetes, was treated with arsenic and the bromides, with which I succeeded in considerably diminishing the amount of sugar in the urine, it having decreased from 94 grammes to 8 grammes to the liter. But my patient, otherwise fairly well-conditioned, was attacked by general caries of the teeth, which frequently happens in the course of diabetes. He went to a dentist and desired to be anæsthetized, which was done. All passed normally, and the patient returned home well pleased. The night following, however, a thirst which had nearly disappeared returned with great intensity, as well as dryness of the mouth and of the general surface of the skin.

"I was called in the next day, and I asked if the patient had been alarmed or excited by the operation, but ascertained that such had not been the case. The urine gave 47 grammes of sugar to the liter, and this condition lasted for about three weeks; then the sugar fell gradually to its normal condition of from 7 to 8 grammes each day.

"I had no thought of the anæsthesia by nitrous oxide having caused the increase of sugar, and three months afterward my patient had another tooth extracted by the same process, with the same success. But the night following the same train of morbid phenomena was produced, and this time the sugar increased to 66 grammes to the liter, and it was only after one month and a half of rigorous treatment that it decreased to the normal condition of from 7 to 8 grammes. Noticing *then* that this aggravation of the diabetes coincided with the anæsthesia by nitrous oxide, I requested my patient in case he suffered again with his teeth not to be anæsthetized. Five months after, according to my advice, he submitted to a dental operation without the use of nitrous oxide, and this time the operation was not followed by any recrudescence of diabetes.

"*Fifth Case.*—An usher of the Sorbonne, to whom I had given my care while I was demonstrator for the chair of physiology, was attacked with mitral insufficiency, the results of which were confined to a dyspnœa variable in intensity: he had never yet had dropsy or albuminuria.

"I was called one day to this patient, and found his legs swollen. I examined his urine and established the presence of albumen. Seeking then for the date of the production of these phenomena, I learned that eight days before the patient had gone to have a tooth extracted, submitting to anæsthesia by nitrous oxide. Since then the dyspnœa had increased and the legs had swollen; pulmonary obstruction had followed, and consecutively albumen had appeared.

"Limiting ourselves to these five observations, which show us accidents of the most varied character immediately following from the same cause, let us seek the relation of the accidents with this single cause.

"Is it nitrous oxide, considered as a chemical compound, that must be incriminated? Is it anæsthesia in general that is the productive agent? Is it the asphyxia that accompanies the production of anæsthesia by pure nitrous oxide?

"*As a chemical composition*, the researches of Hermann in 1864 have demonstrated that nitrous oxide is not injurious by itself, since mixed with oxygen in the proportions of the air it can be breathed indefinitely, without, however, causing anæsthesia. It does not displace the oxygen in the blood; it is not decomposed by it, but remains in a state of solution simply as an indifferent gas.

"*As an anæsthetic agent*, although experimental physiology and pathology may not have attempted anything from this point of view, it has not been explained how a regular normal anæsthesia could be able to produce here an abortion, there a chlorosis, elsewhere the reappearance of epilepsy, or, again, the appearance of dropsy and of the albuminuric cachexia. Surgeons, to my knowledge, have never noted similar accidents as the result of surgical anæsthesia.

"As to the production of diabetes, it might be, so to speak, that after the administration of chloroform there might be an appearance of diabetes, chloroform, as is known since the labors of Cl. Bernard, reducing the liquor of Fehling. I have, however, a personal case which permits me to stand up against this theory. Two years ago—when, in fact, I had not yet given my attention to the possible relations of anæsthesia with diabetes—I was present at a case in which anæsthesia was produced for the reduction of a dislocation of the shoulder of a robust man. I had the curiosity to ascertain if the chloroform was passing in sufficiently large quantity in the urine to produce the reduction of the liquor of Fehling. I ascertained that 30 cubic centimeters of discolored urine did not reduce 4 cubic centimeters of the liquor of Fehling. The next day the same result, whence I can conclude that anæsthesia itself cannot be considered as the factor of the accidents which happened in the observations I have just quoted.

"It is certain, then, as has been established by Jolyet and Blanche in 1873, that asphyxia always accompanies anæsthesia produced by the inhalation of nitrous oxide in a pure state. These physiologists have demonstrated by experiment that insensibility does not begin until there is more than from three to four per one hundred of oxygen in the liquor sanguinis; that is to say, the conditions are the same as where anæsthesia is produced upon asphyxiated animals, according to the studies of M. Paul Bert.

"This result was so striking that it was therefore doubted if nitrous oxide was a real anæsthetic; and the researches of Goldstein in 1876, and also those of Paul Bert in 1879, were necessary to establish definitely the anæsthetic properties of this gas.

"I believe that the state of asphyxia inseparable from the state of unconsciousness necessarily required for the painless extraction of a tooth must bring sufficient disturbance in the placental circulation, and consequently in the fœtal circulation, to provoke an abortion. From another point of view, in an organism so delicate as that of a young girl at the period of adolescence this state of asphyxia can lead to disorders leaving a lasting impression, as that of which I have given an example.

"On the other hand, I understand without explanation that asphyxia in the case of those affected with cardiac disorders aggravates a situation already complicated by the impaired functional power of the central organ of circulation.

"As relates to the reappearance of epilepsy after an anæsthesia produced by nitrous oxide, it is admitted that cerebral excitation provoked by deoxygenated blood is able to produce a pathological cerebral state as yet imperfectly understood.

"But it is very sure that for the aggravation of diabetes following insensibility produced by the inhalation of nitrous oxide one should hold exclusively responsible the asphyxia which is a necessary concomitant of anæsthesia produced by nitrous oxide. In fact, M. Dastre has demonstrated that during asphyxia there is produced a veritable shower of sugar (*une véritable pluie de sucre*) in the blood; and this shower of sugar in a diabetic person under the influence of the inhalation of nitrous oxide gas adds to and aggravates the pre-existing pathological state, as the observations which I have cited prove.

"It is possible even—and I am now making some experiments on this subject—that in an animal or in a person not diabetic anæsthetized by inhalations of pure nitrous oxide there is promoted a temporary diabetes more or less durable.

"I shall make known subsequently the results which I shall obtain.

"What conclusions should I draw from these researches?

"From a purely medical point of view, I will say that anæsthesia produced by inhalation of pure nitrous oxide *is possibly never inoffensive;* that it should be formally prohibited—1st, with pregnant women; 2dly, with young girls at the period of adolescence; 3dly, in the case of persons susceptible to grave nervous disorders; 4thly, in the case of all disposed to cardiac affections; 5thly, in the case of all diabetics.

"In all these cases, when through fear of pain the patient demands to be rendered insensible, chloroform should be used—an agent so easily obtained, so constant in its results, so inoffensive, I may say, when the method so much praised by M. Paul Bert and the apparatus of Dr. Dubois are employed.

"From the point of view of administrative foresight, it should be rigorously forbidden to surgeon-dentists to practise anæsthesia by the administration of nitrous oxide without the assent and assistance of a doctor of medicine. Thus, one would be informed not only of accidents resulting in immediate death—which, happily, are very rare, and which excite the public—but yet, and above all, the secondary accidents, much more numerous, that the same public ignore, notwithstanding their gravity, for the reason that it is difficult to trace their origin back to their first cause—anæsthesia by pure nitrous oxide."

Conclusions.—The writer has no doubt that when attention has once been directed to the subject a much greater body of evidence than has here been presented will be massed in support of the position that the condition of asphyxia incident to anæsthesia by nitrous oxide, when produced in the ordinary manner, is "possibly never inoffensive," and that the gravest pathological manifestations are among its possible results. Thus is afforded still another confirmation of the principle, already incontrovertibly established, that any form of general anæsthesia is a condition of danger, and that on the part of those who assume the grave responsibilities necessarily incurred by the administration of anæsthetic agents there should be demanded the highest intelligence, skill, and learning. The extent to which these requirements have in the past been disregarded, not only among dental, but among medical practitioners as well, needs no comment. With the advanced opportunities for a higher technical training which all progressive dental and medical schools now offer there can be no further justification for ignorance and incompetency, and they must soon cease to be tolerated.

Deaths Following the Inhalation of Nitrous Oxide.—*First Case.*—The first recorded case of death following the inhalation of nitrous oxide appeared in the following report to the *New York Tribune* of Wednesday, January 13, 1864:

"Mr. Samuel P. Sears, a merchant doing business at No. 23 Park Row, on Monday evening called at the establishment of Dr. Joseph Burnett, dentist, No. 373 Canal street, and requested him to extract two or three decayed teeth, also requesting the dentist to administer to him nitrous oxide gas, better known as 'laughing gas.' Mr. Sears being, to all appearances, in perfect health, the operator administered the gas and drew the teeth. The patient seemingly recovered from the effects of the inhalation and went into an inner room, but soon returned and complained of shortness of breath, and sank on a sofa, expiring in a few moments. The deceased was removed to the residence of his parents, No. 274 West Twenty-second street, where an investigation by Dr. George B. Benton revealed the fact that the lungs of the deceased were very much diseased. Dr. Benton is of the opinion that the quantity of gas inhaled would have no injurious effect on a person in ordinary health. Coroner Wildey held an inquest on the body and the following verdict was rendered by the jury: 'We find that deceased came to his death by congestion of the lungs caused by inhaling nitrous oxide gas. We exonerate the person who administered it, but recommend that hereafter an examination be made, by a competent person, of any one who contemplates inhaling said gas.'"

Second Case.—The second case is reported in the *New York Tribune* of February 18, 1864, in the following terms:

"We have now to report another casualty. On the 1st of this month a travelling dentist, at a public exhibition of laughing gas at Swanton Falls, Vermont, administered the gas to several persons. Among the number was a beautiful girl, seventeen years of age, the daughter of W. H. Bell, Esq., a highly respectable citizen. The day after inhaling the gas she was taken ill, although she did not take sufficient to produce insensibility, and died the following day from its effects. Miss Bell presented a strong, robust physical constitution, and was in apparent good health previous to inhaling the gas."

Third Case.—The *New York Tribune* of Feb. 26, 1864, contains the following:

"Another victim is now to be added to the record. As an effort is making to hush the matter in the grave of the deceased lady, her name is not forthcoming. She lived in Allentown, Pennsylvania, and until application to this dentist was generally considered a very healthy woman. This lady applied to have laughing gas administered for painless dental surgery. After having inhaled the gas a few hours placed her in her grave."

Fourth Case.—Charles Kidd, M. D., in a communication to the *Medical Times and Gazette*, London, March 12, 1864, reports that—

"One death has just occurred in a dentist's chair from the administration of nitrous oxide. It was that of a fine young woman in perfect health, who was induced to have this agent rather than chloroform."

Fifth Case.—From the *Medical and Surgical Reporter*, Philadelphia, February 2, 1867:

"Last week Edmund Kerosen, a young man twenty-three years old, entered the office of Dr. Ralph Lee, a dentist of this city, to have a tooth extracted. Anæsthesia was produced by nitrous oxide gas, a cork having been placed between the teeth to keep the mouth open. As the tooth was extracted, we understand, it slipped from the forceps, and with the cork was drawn into the mouth. The tooth was subsequently thrown up from the stomach, but the cork—which does not seem to have been missed—entered the larynx, and by its presence there caused suffocation and death in an hour. A post-mortem revealed the presence of the cork in the larynx and the cause of death."

Sixth Case.—In 1872 in the office of a New York dentist a death occurred which a coroner's jury pronounced to have been "induced by the inhalation of gas administered." The facts concerning this case are given in an editorial in the *Dental Cosmos* (vol. xiv. p. 311):

"From a pamphlet issued by Dr. Newbrough, at whose office the event occurred, we make the following summary of the evidence before the coroner's jury: Dr. Newbrough testified that the patient, a middle-aged lady, desired the extraction of seven or eight front teeth which were *loose*. Dr. N—— advised that their removal would be so easy that an anæsthetic would be unnecessary, but the patient insisted that she could not submit to an operation without it. Dr. N—— then procured a six-gallon bag of gas, but the patient seemed about equally fearful of anæsthesia and pain, and as soon as she had made an inhalation rejected the bag and declared her willingness to have the operation performed without it. At sight of the forceps her courage again failed her, and she decided once more to try the gas. She took one inhalation and again rejected it. By this time so much of the gas had escaped from the bag that the doctor replenished it. Of this she took two inhalations, and peremptorily refused to have anything more to do with it, declaring her determination to submit to the operation. The teeth were then extracted. 'Immediately,' says the doctor, 'she *fainted*, her head dropping over sideways.' The face rapidly became livid, and finally purple, respiration falling to about fifteen per minute. In about thirteen minutes, notwithstanding the prompt application of the galvanic battery and efforts to assist respiration, death ensued. The muscular system was entirely relaxed throughout, and after death the face became instantly blanched.

"Dr. Otis, summoned by Dr. N——, and arriving in about ten minutes after the fainting, testified that he continued the usual restorative treatment for forty-five minutes, when death ensued. At post-mortem found no disease of the heart; brain perfectly exsanguinated in every part; no fluid in any of the ventricles. One lung was more engorged than the other, but healthy."

The coroner's jury, consisting of ten doctors of medicine, rendered the following verdict:

"We find that Mrs. Ann O'Shaughnessy came to her death from asphyxia or apnœa, as evidenced by the symptoms manifested by the patient before death and the conditions found at the post-mortem, the asphyxia having, in our opinion, been induced by the inhalation of gas administered."

This is followed by censure of Dr. Newbrough for using imperfect apparatus in making the gas, only one wash-bottle having been used. Concerning this verdict the *London Lancet* remarks:

"The nitrous oxide could have had no more to do with the fatal issue, either directly or indirectly, than if it had never been brought into the room. The patient manifestly fainted from terror, doing so as soon as her state of mental tension was relaxed by the operation being completed. Her syncope was just a result of the reaction of an overstrung nervous system; and if Mr. Newbrough had only laid her flat on the floor she would probably have recovered in five minutes, have paid him his fee, and have walked away from West Thirty-fourth street as well as she entered it. It was the unwisely holding her upright that determined the fatal issue; and, although one must sympathize with the queer medical jury to the extent of admitting that no anæsthetic agent should be entrusted to a man who treats syncope by the erect posture, yet still when we consider the wide prevalence of his error, we must not be too hard on the dentist. . . . .

"The absence in Mrs. O'Shaughnessy's case of any apparent cause for sudden death other than emotional syncope and the upright posture, and the entire sufficiency of these to explain the occurrence, seem to render the verdict of the New York jury one of the most astonishing on record."

Seventh Case.—"In Chicago, October, 1871, a patient died in the office of a dentist, under the influence of nitrous oxide, two or three days before the great fire which destroyed the most important part of the city. As a consequence of the confusion produced by that event, the fact of this death became known to very few persons, and was soon forgotten."[1]

Eighth Case.—From the *London Lancet*, Feb. 1, 1873, the following is taken:

"A death from the inhalation of nitrous oxide occurred at Exeter in the afternoon of January 22d of this year. The gas was administered by Mr. J. T. Browne Mason, a dentist in Exeter, for the purpose of securing the painless extraction of a large upper molar tooth from a patient under the care of Dr. Pattinson. As this is the first instance of a death from the gas that has been reported upon in this country, the facts are worthy of a special record."

These facts are thus reported by Mr. Mason in a communication to the Odontological Society of Great Britain:[2]

"Miss Wyndham [the patient] was thirty-two years of age, and generally enjoyed good health. There was considerable disorder in the arrangement of the teeth, the second bicuspid on the left side of the upper jaw having what should have been its posterior surface against the lingual surface of the second molar. This tooth had been the subject of so much caries that a probe could be passed right through. The pulp was gone, and there was excessive periosteal inflammation. It was not possible to remove a second molar with the ordinary forceps without disturbing the bicuspid, so Mr. Mason decided to cut off the crown of the diseased tooth, thus separating the fangs,

[1] From *Artificial Anæsthesia and Anæsthetics*, Lyman, p. 325.
[2] *British Journal of Dental Science*, vol. xvi. pp. 126, 127.

and then remove them singly. The patient was accompanied by her usual medical attendant, Dr. Pattinson. The gas (liquid prepared by Ash & Sou of London) was administered in the ordinary way, the patient being seated in a Morrison's chair. The gag used was an ordinary wooden one, and was inserted between the first molar and the second bicuspid. Dr. Pattinson took charge of the pulse in the left wrist. After half a dozen respirations he said the pulse was not so rapid, but its volume had not varied. Mr. Mason then removed the facepiece and cut off the crown of the tooth with the excise forceps. On his thrusting this instrument into the exposed pulp-cavity and twisting the fang, so much pain was caused that the patient declared she could not bear any further operation unless more gas was administered. On rinsing out her mouth the water was tinged with blood. After an interval of ten minutes, the bleeding having quite ceased, the gag was replaced in its former position. Dr. Pattinson, however, thinks there must have been a minute quantity of blood exuding from the gum at the second inhalation. Mr. Mason took charge of the pulse at the right wrist, Dr. Pattinson again having charge of the left, and gas was again administered. Just before losing consciousness the patient raised her hand and pushed off the inhaler, but it was put back. Mr. Mason then attempted to seize the patient's fang with a pair of stump forceps, but, the edge giving way, he dislodged it with an elevator, with which he afterward easily removed the entire fang. The whole operation lasted about three-quarters of a minute. He received all the fragments of the teeth in his fingers, and felt quite sure nothing passed backward. He then for the first time saw the blueness of the face, but Dr. Pattinson had noticed it before. The symptoms then became alarming: the features appeared puffy and swollen, the eyeballs protruded, the breathing became thick and stertorous. The pulse was not observed. An old attendant, who was in the room, exclaimed, 'Take off the gag; she is choking.' It needed great force to separate the jaws, and possibly the gag was then chipped. It was only ten days after the operation that Mr. Braine pointed out for the first time the broken surface of the gag. The head was then thrown forward to prevent any blood from getting into the throat, and Mr. Mason passed his finger over the tongue to draw it forward. From this time Dr. Pattinson was of the opinion that there was fixity of expression and no further entrance of air into the chest. The window was thrown open and cold water dashed in the patient's face. Mr. Mason then went for further assistance, while Dr. Pattinson applied strong ammonia to the nostrils, after which he noticed some water lying in her tongue at the back of her mouth. This he caused to run out by drawing the head forward. When Mr. Mason returned with Dr. Drake the countenance of the patient was black, the face swollen, eyes projecting. Dr. Drake put his finger into the throat, and she made three or four expiratory movements accompanied by a slight sound. The pulse continued to beat regularly for two minutes after the expiratory movement had ceased. Two and a quarter hours after death the blueness had entirely disappeared. It was much to be regretted that a post-mortem examination had not been held."

At the official examination held in this case Dr. Drake testified as follows:[1]

"I am a physician residing in Exeter. Yesterday I was called by Mr. Mason to examine Miss Wyndham. She was sitting in a chair, half reclining, before an open window. Dr. Pattinson was by her side endeavoring

[1] *Op. cit.*, p. 87.

to restore animation. Her features were livid, swollen, and she appeared to be quite unconscious. She breathed a few times, but a short time afterward her pulse ceased to beat. I consider the cause of her death to be paralysis of the parts which regulated her breathing, arising from the administration of nitrous oxide gas, which produced asphyxia."

Ninth Case.—This is a case that excited great attention at the time of its occurrence, owing to the fact that the patient was a surgeon in good practice in Manchester, England. His death occurred in that city March 27, 1877. Mr. Harrisson, it appears, had been suffering from an aching tooth or teeth, and went alone to a dentist, Mr. E. H. Williams, for the purpose of having them extracted. As Mr. Williams was the only witness to the events which followed, his testimony is given:[1]

"I tried to take one tooth out, but deceased, being sensitive, wished to have gas, which I administered in the usual way. I asked him to wave his hand when he had had sufficient. He seemed excited, but it must have been from pain. He said he had had nothing to eat that day and could not live on stimulants. I tried, judging from his appearance that he was ready, to extract the tooth, and then deceased said he must have the gas until he snored. I gave him the gas until he snored, and extracted two teeth. Seeing that he was not coming round, I opened the window to admit air, flapped him, and sent for Dr. Noble."

Upon the arrival of medical assistance Mr. Harrisson was found dead. The post-mortem revealed a great deposit of fat encumbering all the organs, especially the heart. There was enlargement of the liver, due to fatty degeneration, and commencing disease of the aorta and valves of the heart. A great quantity of fluid was found within the cavity of the brain, and there was a general venous engorgement and a fluid condition of the blood. The cause of death was decided to be "sudden failure of the heart's action," although this verdict was vigorously dissented from by many medical writers, who pronounced the death to be due to asphyxia pure and simple.

Tenth Case.—W. Roger Williams, F.R.C.S., surgical-registrar to the Middlesex Hospital, reports the following case:[2]

"This patient, a well-nourished and fairly healthy man, aged fifty-seven, was admitted into the Middlesex Hospital on August 21, 1883, under the care of Mr. Andrew Clark, to whom I am indebted for permission to publish the case. He then presented a considerable cancerous enlargement of his tongue, which was hard and fixed and in places slightly ulcerated. The induration extended from near the tip as far back as the circumvallate papillæ, and involved most of the organ. There was dribbling of saliva. The submaxillary and submental glands on both sides of the neck were enlarged and hard. There was no obvious interference with the respiratory function, but the mouth could not be opened to its full extent. He had been subject to small ulcers on the tongue for several years previously; when young he had chancre and bubo, but there was no other history or sign of constitutional syphilis. His general health had previously been good. There was no history of phthisis, tumor, or cancer in his family. Three months ago he first noticed hardness and stiffness of the left side of the tongue at about its

[1] From *Medical Times and Gazette*, April 28, 1877.
[2] The *British Medical Journal*, October 13, 1883.

middle, which, he said, started in connection with a small sore previously there. The tongue had since been getting larger and harder, but he had had no pain in it. The glandular enlargement was first noticed only a few weeks before his admission into the hospital.

"On the morning of September 15th he was sent to the Dental Hospital in Leicester Square to have some teeth extracted. Gas was administered by the house-surgeon, the patient sitting in the arm-chair in the usual way. The requisite degree of anæsthesia was produced, as far as could be judged, in about thirty seconds. No alarming or unusual symptoms were noticed until the operator was about to begin the extraction, when the patient seemed breathless and even lifeless; then the tongue was drawn forward, water was dashed in the face, and artificial respiration was resorted to, and various other means of reviving were tried for upward of half an hour, at the end of which time they were abandoned, as the patient was evidently dead. About a week previously he had some teeth extracted without the gas, and no unfavorable symptoms occurred then.

"I made the necropsy forty-nine hours after death, the weather being close and fine. The body was well nourished and fairly muscular, and there was a slight degree of rigor mortis present. The back of the head, neck, trunk, and thighs presented a deep purplish discoloration. In reflecting the scalp from the forehead the quasi-fluctuating swelling in this situation, which had been taken for a sebaceous cyst, turned out to be a lipoma. The dura mater was very firmly adherent to the calvarium, and came off with it. In other respects the brain was normal; it weighed fifty-five ounces. The heart was examined *in situ*. There was about the normal amount of fluid in the pericardial sac. Near the apex the visceral pericardium presented a few small whitish patches of fibrous thickening. The organ was rather large and its chambers patent; it weighed twelve ounces. Each ventricle contained about a drachm of fluid blood, but the auricles were empty. The valves were normal, with the exception of a soft miliary fibrinous vegetation in one of the aortic valves, and, as far as could be judged, they were competent. The muscular substance appeared healthy, and there was no indication of fatty degeneration. Evidently, the heart's action had been arrested in diastole, death resulting from syncope. The right lung was firmly bound to the chest-wall throughout its whole extent by old fibrous adhesions; its lower lobe was collapsed, atrophic, and non-aërated, the liver having encroached here on the chest-cavity. The left lung was large and slightly congested, presenting a few small emphysematous sacculations along its free anterior border; in other respects it was perfectly healthy. There were no subpleural ecchymoses or other signs of asphyxia. The left lung weighed nineteen ounces, the right thirteen. The liver was normal; its weight fifty-five ounces. The spleen weighed nine and a half ounces, and was rather large, but otherwise normal. Both kidneys were congested, and presented several small cysts and a few small cicatrices on their surfaces. There were several fibrous patches in both testes, where the secreting structure was destroyed. With regard to the blood, the only obvious change was the absence of clots in the great vessels. A firm whitish mass of cancer, about the size of a small apple, occupied the greater part of the tongue, but the mucous membrane over it was not extensively ulcerated, presenting only a few small erosions; it extended as far back as the circumvallate papillæ. Neither the epiglottis nor the glosso-epiglottidean folds, nor any part of the larynx, was invaded by it. The vocal cords, the rima, and the ventricles were normal. The mucous membrane of the bronchus and its primary divisions was lined with viscid mucus, and its capillary vessels were injected. There were some enlarged and cancerous glands on both sides of the neck."

Eleventh Case.—This occurred in November, 1884, in the office of M. Duchesne, a dentist of Paris. The essential facts relating to the case are contained in the following report of the legal proceedings which were instituted in the case. The report is of interest as showing the status in France, under the law, of dentists other than those who are doctors of medicine, and is here reproduced in full:[1]

"Tribunal Correctionnelle de la Seine (8e Chambre), présidence de M. Mersier, audience du 27 Novembre, 1885.

"Homicide caused by imprudence of M. Duchesne, dentist, death of the patient by asphyxia, Law of Ventose,[2] Year XI., Major Surgical Operations. Decision of the tribunal:

"At the hearing on this day the judge gave in this case the following opinion:

"Whereas, the result of the testimony and of the discussions is that on November 25, 1884, Monsieur Lejeune went to the office of Duchesne to have a tooth extracted;

"That at the request of the patient the dentist gave him nitrous oxide in order to render the patient insensible to the operation;

"That as the result of these inhalations M. Lejeune fell into a syncope which was followed by death;

"Whereas, in this operation Duchesne should have been assisted by a doctor of medicine;

"That the act of administering nitrous oxide requires that the operator have a thorough knowledge of physiology; that he be allowed to examine beforehand, with care, the condition of the organs of the patient desiring the anæsthetic;

"That whatever the experience of the accused may be—experience which suffices in most cases, but not in all—this lack of special knowledge is wanting in Duchesne, who is neither a medical doctor nor an officer of health, though he assumes the qualifications of doctor of medicine;

"That a thorough medical examination of M. Lejeune was very necessary, since his physician knew him to be a man who could not inhale any anæsthetic without danger;

"Whereas, Duschene so fully realized his mistake that in order to exculpate himself he hastened to assert, contrary to the truth, that he had been assisted by a doctor of medicine;

"Whereas, one of the experts, Dr. Brouardel, who was heard at the examination, is of the opinion that for the application of an anæsthetic two competent persons are necessary, of whom one at least should be a doctor of medicine, and that to administer an anæsthetic without observing these conditions is a great imprudence: the same witness testified also that in this particular case it was a special imprudence to give nitrous oxide to M. Lejeune in view of his constitution; that if it had been a question of an operation for a grave malady it would have been admissible to practise on M. Lejeune this mode of anæsthesia, but not when, to quote the language of the witness, it was given out of complaisance and to spare him a little pain in a trifling operation;

[1] From *Le Progrès Dentaire*, Décembre, 1885.

[2] Sixth month of the calendar of the first French Republic, from 19th or 20th of February to 20th of March.

"Whereas, on the other hand, among surgical operations the extraction of a tooth must be generally considered as an operation without any importance, and one which requires chiefly a certain dexterity, any dentist, even if not a graduate, can perform the operation; but when the act is accompanied by the administering of an anæsthetic it is not the same;

"That in this last case, according to the opinion of experts, it belongs to the class of major surgical operations;

"That as a conclusion from this, by the terms of the Article 29 of the law of 19 Ventose, year XI., officers of health, and for greater reasons dentists who are not graduates, have not the right to give an anæsthetic unless under the surveillance and inspection of a doctor of medicine;

"That such an operation is also a contravention of Article 35 of the same law, which prohibits the practice of medicine or surgery without any diploma;

"That a contravention of this kind, when it causes death or injuries, becomes one of the elements of the crime foreseen by Article 319 (Code pénal), which is exactly the crime attributed to M. Duchesne;

"Whereas, finally, the director of one of the dental colleges of Paris does not hesitate to recognize the necessity of the attendance of a physician when it is necessary for a dentist to administer an anæsthetic;

"Whereas, from the circumstances of this case the tribunal has no doubt that the mistake of Duchesne caused the death of Lejeune;

"That such are the conclusions of the experts which are expressed thus: 'We must consider the anæsthetic as having caused death;'

"That it is found that Duchesne did in Nov., 1884, in Paris, by imprudence, carelessness, and neglect of rules, commit an involuntary homicide on the person of M. Lejeune—a crime foreseen and punished by Article 319 of the Penal Code;

"Whereas, however, there exist extenuating circumstances, the penalty is reduced by the application of Article 463, in that which concerns the indemnity called for by the civil party;

"That whereas, from this point of view the court must only consider the material damages resulting to the widow from the death of M. Lejeune;

"Whereas, if this fact has caused the business affairs of M. Lejeune to be retarded, it has at the same time been a source of benefit to his family, since it has caused the annual payments of the policy of a life insurance, which M. Lejeune regularly paid up, to cease, and that the policy of forty thousand francs has been paid by the company;

"That we must also consider that the death of M. Lejeune was not only due to the fault of M. Duchesne, but also by the imprudence of the victim himself, who without consulting his own physician, or without having any medical doctor present, called for the application of an anæsthetic;

"That this imprudence justifies a decree of abatement against the claim of the prosecution;

"That in consideration of these circumstances the sum of three thousand francs is sufficient reparation; Duchesne is condemned to pay six hundred francs penalty to the state, and to pay to the widow of Lejeune the sum of three thousand francs damages. The prosecution is condemned to pay expenses except the fines required from Duchesne."

Summary of Cases.—In judging of the danger of death from anæsthesia by nitrous oxide in the light of the cases of fatality here recorded, Case No. 5 must, of course, be at once ruled out, death in this instance being manifestly due, not to the gas, but to the prop, which produced suffocation.

In Case No. 2 the gas was administered by a travelling mountebank and showman, and in all probability was freshly prepared and in an improper manner, and administered almost as it came from the retort. The death, which resulted on the following day, might well have been caused by the inhalation of poisonous gases and vapors thus produced, and under the circumstances should hardly be scored against nitrous oxide as made and administered by careful and experienced operators to-day.

In Case No. 3 diligent inquiry has failed to substantiate the facts as represented. Dr. Edwin G. Martin, a lifelong resident of Allentown, and one of its leading physicians as well as citizens, says in a letter to the writer: "I have made inquiry in relation to the fatal case from the effects of laughing gas, and cannot find out who the person was. I do not think the lady was from Allentown. No one seems to know anything about the matter." In view of this fact it seems not unfair that this case should be thrown out of the count.

Concerning Case No. 4 there are no data. The sole evidence is the testimony of a reputable physician that a death from nitrous oxide took place in a dentist's chair, and that the patient was in perfect health before the inhalation of the gas. This case may be allowed to stand.

In Case No. 6 so little gas was given, and the symptoms were so evidently those of syncope after fainting, that nitrous oxide should not be held responsible.

Thus out of the eleven cases which have been reported at least four should be eliminated, leaving only seven cases of fatality fairly attributable to the inhalation of nitrous oxide gas out of the many hundreds of thousands of individuals to whom it has been administered since its general introduction into minor surgical practice.

Of the total number of such administrations it is impossible to form even an approximate estimate. Up to January 1, 1887, in a single establishment in this city the gas had been administered 142,780 times. The operator in charge, Dr. J. D. Thomas, writes: "We have never had a fatal case, and are not cognizant of there ever having been any ill effect subsequent to the use of the gas which was not readily accounted for otherwise."

Dr. F. Hasbrouck, a nitrous-oxide specialist of New York City, writes (January 1, 1887): "In the past sixteen years I have administered nitrous oxide to over fifty-two thousand people. I have kept some under its influence (profoundly anæsthetized) one hour and a quarter, many others from twenty to forty minutes. As far as I know, there have been no fatal cases. There have been dangerous symptoms, but they were all in cases of persons who had been afflicted with lung inflammations followed by pleuritic adhesions. In the cases referred to there seemed to be paralysis of the respiratory muscles and entire inability to expand the chest. In such cases my practice has been to place the patients with the head much lower than the feet and keep up artificial respiration. I have had from four to six patients who I think would have died had they not been promptly treated in that way.

After the ability to swallow is restored I administer brandy as soon as possible."

From the figures above given it will be seen that in but two establishments in this country there have been nearly two hundred thousand administrations of the gas, and without a fatal result. Taking into consideration that the agent is in constant daily use all over the civilized world, not only in large cities, but in the smaller towns and villages as well, it is evident that the aggregate number of administrations must have been so enormous as to reduce the percentage of deaths to an exceedingly small fraction, and that, so far as relates to immediate fatality, no anæsthetic agent now known can compare in safety with nitrous oxide gas.

Post-mortem Appearances.

There are no post-mortem appearances which can be said to be strictly characteristic of death produced by the inhalation of any of the anæsthetic agents usually employed: very often an autopsy gives entirely negative results, and very generally, apart from the odor of the drug employed, there is nothing to distinguish such cases from those in which death has occurred from syncope or asphyxia produced by other causes.

Appearances after Death from Sulphuric Ether.—The appearances presented in thirty-two cases of death following the administration of sulphuric ether have been collated by Lyman.[1]

In the First Case.—"The blood was everywhere fluid, very dark and viscous, resembling molasses in the posterior portion of the lungs. The anterior portion of the lungs was filled with frothy mucus: the respiratory mucous membranes exhibited a lively injection; the spleen was very soft."

In the Fifth Case.—"The subarachnoid fluid was more abundant than usual. Brain healthy. Heart soft and flaccid, containing yellow coagula in the right cavities, and a small quantity of fluid blood in the left."

In the Sixth Case.—"The blood was everywhere dark and fluid. The veins of the head contained a considerable quantity of air."

In the Ninth Case.—"The air-passages contained mucosities; the base of the left lung was hyperæmic, the pulmonary tissue itself being impregnated with the odor of ether. The heart was normal, its ventricles empty, its auricles gorged with blood; the nervous centres were healthy."

In the Eleventh Case.—An autopsy held three hours after death found the "blood fluid; brain and membrane normal; a little fluid blood in the heart; base of the aortic valves slightly atheromatous; pleural adhesions over both lungs; lower lobe of right lung œdematous and in a state of red hepatization; rest of the lung normal, but somewhat emphysematous."

In the Twelfth Case.—"The right cavity of the heart was full of dark fluid blood; the left cavity was nearly empty; the valves were healthy;

[1] *Artificial Anæsthesia and Anæsthetics*, pp. 289–297.

the muscular substance flaccid; the lungs were hyperæmic and brightly colored; the brain was normal; all the other organs were healthy."

In the Twenty-fifth Case.—"The heart-substance was slightly fatty; the cavities were nearly empty; no clots; lungs emphysematous; all the posterior parts engorged with blood."

In the Thirty-first Case.—"The autopsy, made the following day, exhibited some œdema of the membranes of the brain; no thrombosis of the pulmonary artery; heart healthy, containing a little blood in the right auricle; ventricles contracted; lungs pale and œdematous; other organs healthy." In the other cases either an autopsy was not held, or if held the results were negative.

In death following chloroform narcosis the appearances presented in the circulatory, respiratory, and nervous tracts are equally variable. Dr. Reese states[1] that "in death from inhalation there is very often no lesion discoverable. At times there will be found considerable congestion of the lungs and bronchial tubes, and likewise of the vessels of the brain, together with a dark and fluid condition of the blood."

The following table from Sansom[2] gives the results of post-mortem examination in fifty-one cases:

Fifty-one Cases of Death from Chloroform Narcosis.

Blood dark and fluid	24
Lungs congested	18
" " in depending parts	4
" loaded with blood	5
" normal	10
Heart, accumulation of blood in right side	17
(In three cases distended; in all the cases there was little or no blood in the left cavities. The blood was fluid in all but two cases. In one case air was mingled with the blood.)	
All cavities empty	9
(In one case contracted from spasm.)	
All cavities containing blood	13
(In one case a firm coagulum was found: galvanism had been employed.)	
Auricles empty, ventricles containing blood	2
Brain congested	9
" normal	14
" pale	7
Air in vessels of brain	1

Dr. Sansom states that an almost constant sign was darkness and fluidity of the blood.

Dr. Snow collated fifty cases of death from chloroform,[3] of the post-mortem appearances in which the following summary is given by Dr. John Chapman:[4] "Of these, thirty-four were examined after death. In three the state of the lungs is not mentioned, in four they are said to be normal, and in twenty-seven there was unequivocal evidence of mechanical obstruction to the action of the heart; the lungs were congested and the pulmonary artery and right heart distended with blood. In some only one of these characteristics is said to have been observed, but in the majority both were present."

[1] *Medical Jurisprudence and Toxicology.*
[2] *Chloroform, its Action and Administration,* p. 147.
[3] *Anæsthetics,* pp. 120–199.
[4] *Med. Times and Gazette,* Oct. 23, 1858.

As given by Tourdes,[1] the following are the principal appearances observed after death from chloroform:

"There is paleness of the face; the expression of the countenance is tranquil; the pupils are dilated; upon the limbs are visible rose-colored spots; there is very little appearance of cyanosis. At its base the tongue is sometimes injected; the retraction of that organ is the physical consequence of the attitude of the corpse when muscular contractility has ceased.

"The lungs are congested, and present a rose-colored tint or even a decided red coloration. This congestion may, in the lower animals, become a disseminated lobular engorgement. In forty-eight cases of autopsy pulmonary congestion has been noted thirty-six times. Sometimes there is serous infiltration of the lung. Great importance has been assigned to the pulmonary emphysema encountered in many cases: this is almost always observed in the lower animals, even if the sudden and convulsive forms of asphyxia have been avoided. Redness of the mucous surface of the trachea and bronchi has often been remarked. A certain amount of froth may be found in the air-passages: the degree of their injection will be more intense if, in a case of homicide or suicide, a few drops of chloroform have found their way into the respiratory tract—an accident which rapidly produces injurious results. It should be remembered that certain authors, among whom Casper may be found, have mentioned an anæmic condition of the lungs.

"A flaccid condition of the heart has been observed (sixteen times in twenty cases). This phenomenon, however, is principally dependent upon the time of the examination. The same remark is applicable to the condition of its cavities (fourteen times out of twenty cases). The muscular fibres of the heart have been found paler than usual. The heart may be filled with blood, especially on the right side. The great veins may be distended with blood, and there is often a sufficiently notable quantity of this fluid in the principal arteries. The blood is liquid, brownish, or of a deep-red color. This condition is rarely absent, Berend having remarked its presence fifteen times in twenty examinations. This fluidity of the blood is coincident with the rapidity of death. Sometimes we have noticed a few clots mingled with the fluid blood; in one case the blood in the left side of the heart had a very deep-red tint, indicative of sudden syncope. Very little importance should be attached to the presence of free gases in the blood, as this is a consequence of putrefaction, which may be very rapidly evolved. A chemical analysis would be necessary in order to determine the character of the gas. In twenty autopsies the presence of these gases was noted seven times. Putrefaction was progressing in three of these seven cases; in three cases the mode of death was doubtful; and in only one case could any value be attached to the observation (Berend).

"The pia mater and the cerebral parenchyma are moderately injected. Congestion is the exception, occurring only four times in forty-eight cases (Sabarth), and it is not considered a cause of death. An anæmic condition of the cerebral organs has been remarked. Their softening seems to be connected with putrefactive changes. We have noted a trifling amount of ventricular fluid. The liver is often congested. This organ is variously affected by the action of deleterious vapors and gases. Injection of the kidneys has been observed."

Appearances after Death from Nitrous Oxide.—In only four of the eleven recorded cases of death following the administration of nitrous

[1] In the *Dict. Encyc. des Sci. méd.*, t. iv. p. 505, from Lyman, *op. cit.*, p. 88.

oxide was a post-mortem examination made, or if made recorded: these cases were the first, the sixth, the ninth, and the tenth. In these cases the appearances were quite as various in their character as those found after death from ether or chloroform.

In the first case the lungs were found much diseased, and "death by congestion" was the verdict of the jury. In the fifth case a cork in the larynx was the cause of death. In the sixth case "the brain was perfectly exsanguinated in every part: no fluid in any of the ventricles. One lung was more engorged than the other, but healthy." In the ninth case "the post-mortem revealed a great deposit of fat encumbering all the organs, especially the heart. There was enlargement of the liver due to fatty degeneration and commencing disease of the aorta and valves of the heart. A great quantity of fluid was found in the cavity of the brain, and there was a general venous engorgement and a fluid condition of the blood." In the tenth case the general condition of the brain was normal. The normal amount of fluid was found in the pericardial sac. The ventricles of the heart contained about a drachm of fluid blood, but the auricles were empty. The blood in the great vessels was free from clots. The left lung was bound down by old adhesions and collapsed; the right lung was healthy.

Local Anæsthetics.

To produce local anæsthesia in painful parts is a primitive instinct of man, and has always been one of the chief offices of medicine. In the attainment of this end not only have such natural agencies as heat and cold, pressure and friction, been resorted to, but the whole list of narcotics has been tested by all possible modes of application, and with results which in the main have been far from uniform, or, as compared with general anæsthesia, certain or satisfactory. The reason for this relative failure is readily found, either in the resistance, greater or less, which superficial surfaces offer to the absorption of pain-obtunding agents, or in the fact that a large number of these exert their chief physiological effects through the nerve-centres, and act directly upon peripheral nerve-tissue only in a modified and lessened degree; so that the local analgesic effect of even so powerful a sedative as morphia is often quite insignificant, although it may have been applied hypodermically, and thus brought in direct contact with the tissues it was sought to influence. For these reasons not only have local applications for the relief of pain, but for its prevention, proved to a great extent ineffective.

Local anæsthesia of the teeth and their investments is, owing to their density of structure, especially difficult of attainment by medication. Applications to the dental pulp when fully enveloped by its normal coverings of dentine, enamel, etc. would appear to be almost futile. In those cases, however, when, as the result of caries or accident, these have been broken down and the pulp thus made accessible to the direct contact of anæsthetic or analgesic agents, very uniformly successful results are attainable; and, indeed, in such cases at least temporary relief from pain is almost invariable when the proper agent has been judiciously applied. Even with so vascular an organ as the dental pulp, however, the anæsthesia produced is, as a rule, superficial and transitory, and while pain may be absent as long as the tissues are at rest, any attempt at surgical interference causes a renewal of the suffering, so that when pulp-extirpation is attempted its removal in mass under local anæsthetic influences is rarely practicable; and it is generally necessary to anæsthetize—and, in turn, excise—fibre by fibre, to the finest ramifications of the pulp-substance—a process even then not often to be accomplished painlessly.

The agents which will most readily effect local analgesia of the exposed dental pulp are creasote, carbolic acid, oil of cloves, and oil of cajeput, these to be used alone or in combination with morphia. A mixture made by rubbing up the acetate of morphia with enough oil of cloves to form a thin paste has, in the writer's experience, rarely failed to afford prompt relief in pulp inflammations. A sixth of a grain may be employed, this being placed in the affected tooth upon a pledget of cotton; and to secure its greater efficacy, as well as to avoid the possibly serious consequences which in the case of children might result from swallowing the drug, the application should be carefully sealed in the carious cavity with one of the softer preparations of gutta-percha, great care being taken to avoid pressure upon the exposed pulp during the process. The cavity should, of course, be previously well cleansed in order to ensure the close contact of the medicament with the exposed surface: this is a preparatory measure highly desirable in all cases, and often essential to success whatever agent may be employed.

In addition to the agents above named other volatile oils, such as oil of wintergreen and oil of eucalyptus, have been extensively used. The success of ether and chloroform in the production of general anæsthesia early led to a trial of their local anæsthetic effects, and they have been much employed, generally, however, in combination with other substances. But in pulp-exposure their volatility and the irritation of the gum-tissue which they produce when held in close contact with it interfere with their usefulness. A solution of camphor, either in ether or chloroform (ʒj to fʒij) has been recommended, and when better means are lacking may be successfully employed.

Aconite has also been largely used in all forms of odontalgia. In the relief of pain arising from pulp-exposures the writer has not found it so efficacious as the preparations previously recommended. As an analgesic application in peridental inflammation it is hardly more successful, for although a distinct benumbing of the parts can be secured, this is usually but slightly alleviatory in character, and to obtain even this simply painting the gum with the tincture is quite a futile procedure. For its successful use free applications are necessary. The writer's practice is to saturate with the tincture quite a large pledget of cotton-wool and place it upon the gum-tissue over the affected tooth, allowing it to remain there for some hours, and renewing if necessary. There is with an adult no danger from this practice if the saliva is carefully ejected as it accumulates. With many practitioners combinations of aconite with iodine or with chloroform are favorite applications in this class of cases. As chloroform favors the inward osmosis of alcoholic solutions, that combination at least would appear to be justified on physiological grounds, although if added to aconite in any considerable amount a prolonged application such as that just described for aconite alone would be exceedingly painful, and would inevitably cause the formation of a blister if not even more violent inflammatory effects. This too is true of combinations of aconite and iodine: only a simple painting of the gum is permissible, unless counter-irritant effects are desired. Iodine without admixture with aconite will frequently not only reduce the pain incident to the chronic type of peridental inflammation, but will also produce a marked amelioration of the other symptoms. This result may be due in part to contraction of the congested capillaries, but in the writer's opinion iodine in the class of cases indicated often exercises a slight but specific sedative influence.

Iodoform, which has come into such general use during the present decade, has in many cases proved very effective as a local anæsthetic, one of the chief barriers to its usefulness in dental practice being its penetrating, persistent, and unpleasant odor, and an insolubility so great that even ether and chloroform dissolve it but sparingly. Its odor it is impossible to entirely disguise; it may, however, be modified by the addition of the various aromatic oils. To ensure the contact with tissue to be medicated of a definite amount of the drug, its intimate mechanical admixture with other solids has been resorted to, as in the following formula:

℞. Iodoformi (pulv.),
Kaolin. (pulv.), *āā*, gr. ix;
Acidi carbolici (crystals), gr. viij.

Mix and add enough glycerin to form a paste, then add—

Olei menth. pip. gtt. x.

Signa. Place a small portion of the mass upon the exposed surface, using either the point of a probe or a pledget of cotton as the carrier; then carefully seal the cavity.

As a deodorizing formula the following has been suggested:

Take of	Iodoform,	100 parts.
	Oil of peppermint,	5 "
	Oil of neroli,	1 "
	Oil of lemon,	2 "
	Tincture of benzoin,	2 "
	Acetic acid,	1 "

Powder the iodoform and thoroughly mix with the other ingredients. Transfer to a well-stoppered flask and keep for two days over a water-bath at a temperature of from 120° to 140° F. The aroma of the freshly-roasted coffee-berry is also very efficient in disguising the odor of iodoform, and a preparation known as caff-iodoform, of which coffee forms one of the constituents, is now much employed. It is prepared by reducing the coffee-berry to an impalpable powder and thoroughly combining it with the iodoform in the proportion of 50 per cent.

Whenever iodoform is placed in a tooth, the cavity should be sealed if practicable, as in some subjects the taste and odor produce nauseating and irritative effects.

Menthol, a peppermint camphor obtained in a crystalline form by the exposure of Chinese oil of peppermint to cold, has proved very effective as an analgesic in pulp-irritations, and has also been thought to obtund pain in sensitive dentine. As it is a much more volatile substance than the officinal camphor, and readily melts at the temperature of the body, it may for either purpose be placed in substance in the affected tooth. Usually, however, it is used in solution, either in carbolic acid, creasote, the oil of cloves, or the oil of cajeput, it being freely soluble not only in these substances, but in all oils, fixed and volatile, and also in alcohol, chloroform, and ether. A good formula for dental purposes is as follows:

℞. Menthol. gr. v;
Olei caryophylli, f℥j. M.

As a local application for neuralgia the following combination will often be found effective:

℞. Menthol. gr. v;
Olei cajuputi, f℥j. M.

S. Apply with a camel's-hair pencil to the seat of pain.

Menthol in substance rubbed over neuralgic areas is now a frequent form of medication, and is one among the many popular remedies for headache, having too, like other "cures," its share of successes. As menthol when swallowed often excites considerable nausea and gastric irritation, care should be exercised in its use in the mouth.

Cocaine.—Although infusions and other preparations of coca-leaves have for some years been used for diminishing the irritability of the pharynx and larynx, it was not until the publication, in 1884, by Koller, of his discovery that a solution of the alkaloid applied to the eye would locally anæsthetize the conjunctival and corneal surfaces of that organ, that public attention was called to the great value of the drug in general medical and surgical practice. Although so recently introduced, cocaine has already secured its place as easily chief of all known local anæsthetics; and while in dental surgery the results obtained from it have not been nearly so uniform or satisfactory as in other departments of the healing art, still its great value has been fully demonstrated, and further experience in its preparation and use will doubtless do much toward overcoming the obstacles which at present, in many instances, prevent the full development of its physiological effects.

Owing to the importance of this agent, the following facts concerning its history and preparation are here given:

Cocaine is an alkaloid obtained from the leaves of *Erythroxylon coca*, a plant cultivated in Peru, Colombia, and Bolivia on the slopes of the Andes, and which has long been in almost universal use among the aborigines as a tonic and stimulant, the Indians claiming that by chewing the leaves their physical powers are greatly increased, so that they are enabled to endure great bodily exertion with comparatively little exhaustion or fatigue. The term "erythroxylon" refers to the red color of the wood of some of the plants of the genus, while the word "coca" is said to be derived from the Indian word *khoka,* signifying the plant or shrub.

A writer in the *London Lancet*[1] gives the following description of the plant:

[1] December 13, 1884.

"The coca-shrub grows to a height of from four to eight feet, and resembles our blackthorn in appearance. It has small white, short-stalked, drooping flowers, in clusters upon the branches in places where the leaves have fallen. The leaves are closely placed, alternate, about two inches long, oval oblong, entire at the margin; sometimes they are acute, but usually blunt and emarginate, with a small apiculus in the notch at the apex, rather thin, but opaque, smooth with a prominent midrib, and on each side a curved line running from the base to the apex, showing its mode of venation. When fresh the upper surface is bright dark-green in color; the lower is paler and strongly marked with veins. The carefully dried leaves have the odor of tea, but if dried less perfectly they have a bouquet of their own, which is very unpleasant in the breath of those who chew it. They have a somewhat aromatic and bitter taste, and are more active when freshly dried. By permission we have tasted a fresh leaf in the Botanic Gardens, and the benumbing effect on the tongue, dulling its sensibility, was apparently much greater than that of a number of dried leaves. The plants are raised from seeds, and the cultivation, at an elevation of from two thousand to seven thousand feet above the sea-level, is carried on with great care. Five years are required for the full growth; the first crop of leaves is gathered at the end of a year and a half."

The alkaloid was first isolated from the leaves in 1855 by Gardeke, who called it erythroxylin. In 1860, Dr. Niemann made a thorough study of the plant and gave to the alkaloid the name, cocaine, by which it is now known. According to Lossen, its chemical composition is $C_{17}H_{21}NO_4$. Its crystallization is in monoclinic prisms, and 704 parts of water are required to dissolve it. In alcohol and ether it is more readily soluble. The taste of cocaine is bitter and its reaction strongly alkaline.

Hitherto, the cocaine hydrochlorate has been the salt most experimented with, but the citrate, salicylate, borate, oleate, and hydrobromate, as well as other salts, have been introduced with results which, while more or less satisfactory, are as yet not conclusive as to their relative value. In dentistry the hydrochlorate in aqueous solution, the strength varying from 2 to 10 per cent., has been chiefly used, the best average results having been obtained with a solution of 4 per cent.

Cocaine hydrochlorate is soluble, not only in water, but also in alcohol, ether, chloroform, glycerin, the volatile oils, etc. The following formula will give a 4 per cent. solution in water:

Take of Cocaine hydrochlorate, $2\frac{1}{4}$ grains;
Distilled water, f℥j. Mix.

The fact that the aqueous solution of cocaine is liable to deteriorate when kept for any considerable length of time has been no inconsiderable barrier to its successful employment, many cases of failure being doubtless due to this fact. The use of various preservative agents has been recommended, such as the substitution for pure water of distilled water containing seven grains to the pint of either thymol or salicylic acid. Camphor-water has also been successfully tried. As the result of numerous experiments with these agents during a period of six months a writer in the *Ephemeris* (May, 1885) affirms the "strong probability" that boric acid in the proportion of one-half of 1 per cent. will protect cocaine solutions until they are used up in ordinary practice. The best results, however, are obtained when fresh solutions are made for each application or for use during each day. By making suitable subdivisions of a grain of the drug, and dropping upon the quantity selected the required proportions of water, using a graduated minim pipette for the measurement, very small amounts of a definitely proportioned solution can be obtained, and thus both waste and deterioration be avoided.

Physiological Effects.—Taken internally in large doses, cocaine may cause gastric irritation, this, however, being temporary in character, as local anæsthesia of the mucous lining of the stomach speedily ensues; to which influence is probably attributable the absence of the sense of hunger experienced by those who chew the leaves. The introduction of moderate amounts of the drug into the system is followed by increased action of the heart and quickening of the respiratory movements, the temperature being at the same time increased. In large doses, however, the action upon the circulation and respiration is depressant, paralysis of the lungs ensuing and the movements of the heart being arrested in diastole (Riggs). Both the motor and sensory nerves are depressed, but the sensory system chiefly and primarily. To the latter influence is due its anæsthetic effect upon all vascular surfaces with which it is brought into local contact, this being especially marked in the eye, both the conjunctiva and cornea being made insensitive to touch within a few minutes after the application of the drug, the effect continuing during half an hour. Marked mydriasis also results, the dilatation of the pupil frequently continuing during several hours, and being attended by uncertainty of vision and interference with the power of accommodation. A notable effect is upon the capillary blood-vessels, which are caused to contract. For this reason cocaine has been found a valuable hæmostatic; and even though the observation of Moore be correct, that contraction of the blood-vessels is, within twenty-five minutes, followed by a dilatation greater than their original calibre, still even a temporary contraction is of value, in that it favors the formation of clot.

Application of Cocaine in Dental Practice.—As has been intimated, the use of cocaine in dentistry has been successful only in a limited degree, the percentage of failures, especially in the treatment of sensitive dentine, being very large—a result sufficiently accounted for by the dense and relatively impermeable character of tooth-structure, and the consequent difficulty of securing with the anæsthetic agent a degree of saturation of the contents of the tubuli sufficient to obtund sensation. Contrary to reasonable expectation, this difficulty does not appear to be lessened in the case of young children, whose teeth, being less dense than those of adults, might therefore be assumed to be more permeable, whereas in point of fact better average results can be obtained with adults than with the very young. The writer's experience leads him to attribute this result to extraneous conditions, such as the great nervous excitability of the subject, and, as an indirect consequence, the difficulty of effectually removing débris, softened dentine, etc. from the carious cavity before applying the solution; while a third factor may be found in the profuse salivary outflow which in this class of cases so soon floods the mouth, and of necessity rapidly lessens the strength of the anæsthetic application unless the latter be protected by the use of the rubber dam.

Another circumstance demanding attention at this point is the fact that the use of the rubber dam as a means for the protection of the solution prevents rather than favors the anæsthetic power of the drug. This is the experience of the writer, and is confirmed by the observation both of Thompson and Raymond, each of whom has placed on record the results of extended and intelligent experimentation. Dr. Raymond[1] reports failure with but a single exception: he states that "the cavities of decay have been carefully dried, being protected by the rubber dam, and a solution of the salt varying in strength from 4 to 10 per cent. has been put in the cavity. After a lapse of from three to six minutes this was repeated. In some instances I have called into requisition the hot-air syringe. In only one case has there been any appreciable loss of sensation, except where the heat from the syringe was continued and the dentine so thoroughly dried as to check the circulation through the tubuli. . . . . I have tried no less than thirty cases by instillation in the mouths of as many persons without any apparent diminution of pain."

This result, corresponding to the experience of Dr. Thompson, is by him attributed to an interference with osmotic action by the contents of the tubuli, resulting from the absence of the salivary moisture, the dry dentine absorbing a portion of fluid from the solution, but "not sufficient to obtain the toxic, benumbing effects necessary to insensibility."

To the writer, however, it hardly seems probable that any considerable desiccation of tooth-structure can go on in immediate presence of an aqueous solution applied, as is usual, in liberal amount; and a more plausible explanation of the phenomenon would seem to be, either that the alkalinity of the saliva favors osmotic action through its greater affinity for the probably subacid contents of the tubuli in a carious tooth, or that the presence of the rubber dam, closely applied, shuts off entirely all action upon, or absorption through, the gum-tissue or the peridental membrane, whose exalted sensibility, either directly or by reflex irritation, is often no unimportant element in the production of the painful sensations experienced by the patient in, or referred by him to, the implicated tooth.

Whatever may be the truth as to theories, the fact remains that the best success is obtained by applications made directly to the unprotected tooth. These it is generally necessary to renew from time to time. Dr. Thompson[2] recommends the following procedure: "Apply the 4 per cent. or 5 per cent. solution for twenty minutes. If not quiet, reapply for the same time, and repeat if not conquered. If not insensible then or nearly so, reapply for the same time, and repeat as often as may be necessary. If, after repeated applications, the pain cannot be controlled, you will of course acknowledge defeat. But there are very few cases which four or five applications of twenty minutes each will not conquer; usually two or three will suffice."

As is fully recognized by Dr. Thompson, this slowness of action con-

[1] *Dental Cosmos*, April, 1885. [2] *Ibid.*, June, 1885.

stitutes an almost insuperable barrier to the practical usefulness of the drug in every-day office routine. When such prolonged periods of time can be spared by patient and operator quite as good average results will be obtained in cases of sensitive dentine by the thorough drying of the cavity and its exposure, protected by the rubber dam, to the desiccating effects of ordinary atmospheric air, under which conditions the abstraction of moisture from the tubuli, and the consequent inhibition of functional activity on the part of their protoplasmic contents, will be so gradual as to occasion but little if any suffering. The same result can be much more rapidly attained by Dr. Register's process of throwing into the carious cavity from a storage-reservoir a steady current of air warmed to the body temperature.

Similar results are often sought for by the use of substances, such as absolute alcohol, tannin, mineral acids, zinc chloride, etc., having a strong affinity for water and at the same time producing coagulation of the albuminoid constituents of organic matter. These applications are, however, usually superficial in their action, and are often intensely painful.

The use of arsenious acid, the most potent of the pain-obtunders belonging to the escharotic group, is as a rule entirely inadmissible, owing to the pulp-devitalization which almost invariably follows its employment.

The unsatisfactory character of the results obtained by the use of cocaine as a direct local application has led Dr. Raymond and others to produce dental anæsthesia by the direct application of the agent to the main branches of the nerves supplying them with sensation. Dr. Raymond gives reports of several cases coming under his observation, one of which is the following:[1]

"Dr. W——; cavity on the posterior surface of the right inferior first molar; excessive sensibility on touching it. Caries had not caused much loss of the dentine covering the pulp. That organ was well protected and in a normal condition. The syringe was charged with thirteen minims of a 4 per cent. solution of cocaine, and the needle-point directed on a line extending about midway between the angle and the coronoid process of the inferior maxillary, passing through the internal pterygoid muscle. The finger being placed upon the internal oblique line as a guide, the syringe needle was carried along the inner surface of the ramus until it reached the nerve as it enters the inferior dental foramen. A 'tingling' sensation was produced in the bicuspids and incisors when the syringe was discharged. In three minutes the tongue began to feel numb and thick on the right side. In seven minutes there was almost complete anæsthesia of the right half of the tongue and the gums around the inferior teeth. The excavator being applied to the cavity, which was previously so tender, no sensation whatever was felt by the patient. I then used the engine with perfect freedom, and prepared the cavity for filling without any discomfort to him. Although there was just a slight degree of sensibility in the bottom of the cavity, he said it amounted to nothing comparatively; he was just conscious that the instrument was there. The gustatory nerve, which lies near the inferior dental at the point injected, accounts for the tongue being anæsthetized. As the gustatory was not touched, this shows that it

[1] *Dental Cosmos*, April, 1885.

is not necessary for the needle to penetrate the nerve-substance. The cervical portion of the cuspid on the left side was very painful to touch, owing to the denudation of the soft tissues that covered it; but while operating on the side injected the cuspid, although being in the same condition as the other, could be rubbed with a steel instrument without the slightest manifestation of pain. The anæsthesia lasted for about twenty-eight minutes, when normal sensibility returned. That evening, at dinner, there was some stiffness and a slight soreness in the muscles while masticating on the right side. The next morning there were no symptoms indicating that he had submitted to any unusual treatment."

Dr. R. J. Hall of New York gives the following report of the local anæsthesia of the superior maxillary nerve practised upon his own person:[1]

"This afternoon, having occasion to have the left first upper incisor tooth filled, and finding that the dentine was extremely sensitive, I induced Dr. Nash of 31 West Thirty-first street to try the effects of cocaine. The needle was passed through the mucous membrane of the mouth to a point as close as possible to the infraorbital foramen, and eight minims were injected. In two minutes there was complete anæsthesia of the left half of the upper lip and of the cheek somewhat beyond the angle of the mouth (as I was in the dentist's chair, I could not determine the exact limits), involving both the cutaneous and mucous surfaces; also of the left side of the lower border of the septum nasi and of the anterior surface and lower border of the gums, extending from the median line to the first molar tooth. Forcing the teeth apart with a wedge caused no pain except when the wedge impinged on the unaffected mucous membrane of the posterior surface of the gums. Dr. Nash was then able to scrape out the cavity in the tooth, which had previously been so exquisitely sensitive, and to fill it, without my experiencing any sensation whatever. The anæsthesia was complete until twenty-six minutes after the injection, and sensibility was much diminished for ten or fifteen minutes longer. Piercing the mucous membrane with the needle caused pain like the prick of a pin, but its subsequent introduction until it struck the bone, and the injection of the solution, were not felt. . . . . In the experiment upon the teeth it surprised me that the incisor tooth should be rendered insensitive, as the antero-superior dental nerve is given off in the infraorbital canal. I can only suppose that the effect extends some distance along the nerve centrally, or that the fluid travelled along the sheath of the nerve into the canal."

Dr. Raymond's directions as to the method of preparing and using cocaine in this manner are as follows:

"The only way to get good results with the cocaine is to obtain a quantity of the soluble alkaloid and mix it at the time of using it. The requisites are a minim glass, a pair of scales, some filtering-paper, and a little water that has been boiled. It is necessary to have an easy-working syringe, with a perfectly smooth, sharp needle. Care must be taken to exhaust the air from the syringe when charged ready for use. This can be done by drawing in more of the solution than is needed, and pressing it out to the required number of minims. Hold the needle-point up, so as to allow the air to get above the solution; then press the piston."

While the experiments above recorded are exceedingly interesting

[1] *New York Medical Journal*, Dec. 6, 1884.

from the physiological standpoint, and while they testify to the skill and courage of the operators, still the writer ventures the opinion that in view of the possible consequences of this method of applying cocaine, such as the perforation of arteries or veins, injury to nerve-tissue, etc., the cases in actual practice are very rare in which its employment can be considered justifiable or expedient, and in which it would not be much better to give moderate doses of the safer of the general anæsthetics, as, for example, nitrous oxide gas, a few inspirations of which will speedily produce an analgesic effect upon the most sensitive teeth, and without the abolition of consciousness. While it is true that the duration of the influence is short, still it usually suffices for a rapid operator to accomplish the more painful details necessary in the preparation of the tooth; if not, additional doses can be given from time to time as may be needed. As a local anæsthetic in tooth-extraction cocaine has been found too superficial in its action to give satisfactory results. By deeply injecting it into the gum-tissues around the tooth to be extracted, however, a decided mitigation of the pain may sometimes be secured.

The Herbst Obtundent.—What is now known as the Herbst obtundent consists of a saturated solution of cocaine hydrochlorate in chemically pure sulphuric acid, to which solution sulphuric ether is added to the point of saturation, all excess of ether floating upon the surface and evaporating. According to Harlan, seventy grains of cocaine hydrochlorate are required to saturate two drachms of the acid. Even with this preparation, however, several applications are required before anæsthetic effects are developed.

Prof. Harlan[1] recommends a solution of cocaine hydrochlorate, ten grains in ninety minims of sulphuric ether, and states that applied to an exposed pulp for four or five minutes its painless extirpation can be accomplished.

Kava-kava Resin.—This substance is obtained from the root of the *Piper methysticum*, a shrub found in the Sandwich Islands, *kava-kava* being the native name for the root of the plant. Dr. Lewin was the first to call attention to the local anæsthetic power of this resinous extract; hence the name "Lewinin" has been proposed for it. Taken into the mouth, it is found to produce numbness, tingling, and finally local insensibility, accompanied by some pallor of the mucous membrane. Applied to the eye, it will produce complete insensibility of the conjunctiva and cornea. It is, however, too irritant in its effects to be employed in ophthalmic practice. Dr. Harrison Allen has derived very satisfactory results from the application of a 50 per cent. alcoholic solution to oral and naso-pharyngeal surfaces. Its usefulness in dental practice has not been determined.

Drumine.—Concerning this new claimant for place in the list of local anæsthetics, the following account is given in the *British Medical Journal*, January 1, 1887:

"An alkaloid has lately been obtained from the plant, *Euphorbia Drummondii*, N. O. Euphorbiaceæ, by Dr. John Reid of Port Germein, South Australia, which promises, if report be true, to compete with cocaine as an

[1] *Dental Review*, January, 1887.

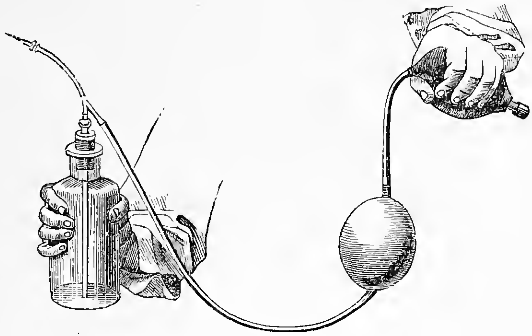
agent for producing local anæsthesia. A tincture of the plant is made with rectified spirit or proof spirit acidulated with hydrochloric acid, and, after standing a few days, the spirit is distilled off, ammonia added in excess, and the whole filtered. The residue, after the smell of ammonia has disappeared, is dissolved in dilute hydrochloric acid, and filtered through animal charcoal to destroy the coloring matter, which is abundant and inactive. This filtrate is evaporated slowly and leaves the alkaloid. It gives a colorless solution with little taste. It is almost insoluble in ether, freely soluble in chloroform and water, and deposits from solution microscopic acicular and stellate crystals. The crystals deposited from the hydrochloric solution filtered through animal charcoal are circular or boat-shaped. They are colorless, and seem to be less soluble in chloroform. Sheep and cattle are stated to die in great numbers annually in consequence of having eaten this plant, the poisonous qualities of which vary in proportion to the quantity of milky juice present. Sheep, bullocks, and horses die in from twenty-four hours to seven days after eating it, all of them presenting paralysis of the extremities, some of them hanging the head as if tipsy; the appetite does not appear to be interfered with. It is curious that the animals avoid the weed at first, except under pressure of hunger, but, once having partaken of it, they seek for it and eat it with avidity. Injection of a solution of the alkaloid into the nostrils of a cat produced stupidity and indifference to stimuli, with a placid, stupid expression, like that of an animal under the influence of a narcotic. The limbs appeared paretic. A few drops of a 4 per cent. solution dropped into the eyes of another cat produced insensibility to the extent of allowing the conjunctiva to be touched, and the orbicular muscle no longer contracted with the same vigor. The pupil was not appreciably dilated. Three grains were then injected subcutaneously, but beyond local anæsthesia no effect was noted. A larger dose by the mouth promptly produced paralysis of the limbs and slow, difficult breathing. When dying strychnine was injected, but failed to produce any muscular contractions. Ten minims of the 4 per cent. solution injected into the hind leg of a cat seemed to produce paralysis of sensation, but not of motion. No convulsions ever followed its use. In the course of experiments on his own person Dr. Reid found that the drug produced anæsthesia, with loss of taste when applied to the tongue or nostril: but small doses swallowed were not followed by any perceptible constitutional symptoms. He tried it subcutaneously in a case of confirmed sciatica in an old man, and the essay was followed by complete and, so far, permanent relief; in sprains it was very useful in relieving the pain. Dr. Reid recommends the use of the alkaloid in small operations, local irritation, and sprains."

Local Anæsthesia by Freezing.—The first to suggest this process was Dr. B. W. Richardson, who in 1866 proposed the application of ether spray to the part to be incised, the rapid volatilization of the ether causing the abstraction of heat from the tissues to a degree sufficient to thoroughly freeze them. For this use it is necessary that the ether should be highly rectified, and, as far as possible, be absolutely free from either alcohol or water.

The use of rhigolene was subsequently introduced by Prof. Henry J. Bigelow, this fluid, owing to its greater volatility, producing frigorific effects even more rapidly than does ether. In dental practice, however, the results obtainable from rhigolene are not so uniformly satisfactory as with ether. With the latter agent the anæsthesia seems to be more complete—a fact which is, in all probability, due rather to its systemic than its local effects, as when ether spray is thrown into the mouth the patient must inhale no inconsiderable amount of the vapor.

For the application of either of these agents in the extraction of teeth the atomizer represented in Fig. 29 is well adapted. Through a perfo-

FIG. 29.

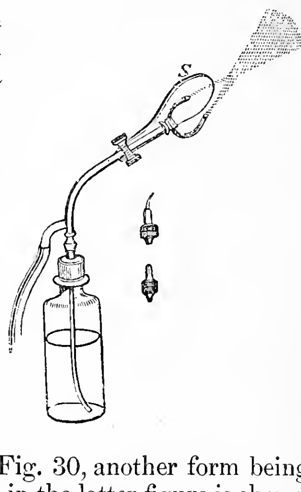


rated cork in the bottle containing the ether passes a double tube, one extremity of the inner part of which is made long enough to reach to the bottom of the bottle. Above the cork a tube connected with the elastic bulb which forms the bellows pierces the outer part of the double tube, and communicates by a small aperture at the inner end of the cork with the interior of the bottle. The inner tube for delivering the ether runs upward to the extremity of the outer tube.

When the bellows are worked a double current of air is produced: one current, descending and pressing upon the ether, forces it along the inner tube; the other, ascending through the outer tube, plays upon the column of ether as it passes from the inner tube. In the figure the bulb compressed by the hand is the bellows bulb; the other serves as a storage reservoir, thus keeping up a steady pressure upon the ether and producing a continuous jet. A straight nozzle may be used when only a single jet is required, but for operations upon the teeth a double jet is usually desirable, the spray to be directed both upon the palatine and buccal or lingual surfaces of the gum-tissue. This can readily be accomplished by means of the double nozzle seen attached to the bottle in Fig. 30, another form being represented as in operation in Fig. 31. At *s* in the latter figure is shown an appliance devised by Dr. James E. Welch for pressing away the lip

FIG. 30.

FIG. 31.



or cheek from the teeth to be operated upon, thus to a certain extent protecting it from the action of the spray.

Owing to the introduction of nitrous oxide the use of this method has been very generally abandoned, although it is still occasionally resorted to by some practitioners. There can be no question as to its efficiency in obtunding the pain incident to the actual extraction of a tooth, although it is often questionable whether the suffering occasioned by the freezing process and the reaction therefrom is not almost as great as would have been the extraction without anæsthesia. There is also frequently considerable difficulty in limiting the freezing process to a single tooth. No inconsiderable objection to the use of these agents is the penetrating odor which permeates the apartments in which they have been employed, as well as the clothing of the operator. Ether is especially obnoxious in this respect, the odor being very persistent.

As with other processes, the skill and experience which come from practice will do much toward overcoming the difficulties and disadvantages incident to their employment.

When a large, hollow, devitalized tooth is to be extracted, the root-investments can generally be sufficiently benumbed by throwing the spray into and upon the tooth itself, without impinging to any considerable extent upon the gum-tissues; and, although considerable time is necessary, this is by all means the most desirable method of securing local anæsthesia by cold in this class of operations. The method has this further advantage, that by placing around the tooth a sheet of rubber dam the non-conductivity of that material will to a great extent protect adjoining teeth from the action of the spray.

As a rule, however, the freezing must be accomplished through the gum and alveolar walls of the tooth. The pain incident to the first impact of the spray upon these surfaces is generally very great, especially in cases of pulp-irritation; but much can be done to modify this inconvenience by proceeding slowly with the process, and at first throwing upon the parts only small volumes of spray. Sensation may in this way be gradually and quite painlessly abolished, the spray being then thrown with more and more vigor until the parts are thoroughly frozen, as evidenced by the perfect blanching, the hardness, and the insensitiveness of the tissues. This is a condition of things readily recognized, as the gum becomes quite bloodless and white.

When this process has been carried far enough, the extraction of a tooth is rarely attended by actual pain, although as long as consciousness lasts the sensation can never be otherwise than one of discomfort. The reaction, however, is always painful, and frequently intensely so. This can be in a measure obviated by applications of ice or of ice-water to the parts, so as to make the process more gradual.

The application of the freezing process to the lower teeth is frequently attended with difficulty, owing to profuse salivary outflow: this source of embarrassment can best be overcome by the use of a saliva ejector. The tongue should be held away from the tooth to be operated upon by a suitable depressor, between which and the tongue a napkin should be placed for the further protection of that organ against the action of the spray. Both in the upper and lower jaw the tissues of the cheek should be carefully shielded by analogous means or by the shield shown in Fig. 30.

Although sloughing is one of the dangers of the freezing process, the possibility of which should always be borne in mind, it has rarely occurred in dental practice, the great vascularity of the parts and the limited area operated upon serving as a safeguard against this untoward result. The accident is far more likely to occur in those cases in general surgery where extended surfaces are frozen to a hardness so great as to render cutting with the knife a matter of such difficulty as to compel the use of strong curved scissors—a substitution suggested by Dr. Richardson.

As a substitute for ether or rhigolene spray Mr. James Arnott of London has suggested the employment of freezing mixtures, of which the most convenient is the well-known mixture of ice or snow and common salt, the rapid liquefaction of which when in contact causes the abstraction of heat from the surfaces upon which the mixture rests. The proportions which secure the best results are two parts of crushed ice and one part of salt. These should be thoroughly mixed and placed in a bag of gauze or other thin fabric through which the water can drain as rapidly as it is formed—a condition greatly favoring success—and then applied to the part to be frozen. This method has been employed in dental practice, and by making bags of suitable size, and having the ice and salt finely pulverized, successful results can be obtained. In making bags for this purpose the side to be placed next the cheek or tongue should be covered with sheet rubber, for the protection of those parts from the action of the cold. As the taste of the brine is exceedingly disagreeable, a soft napkin should be placed upon the tongue to receive the liquid as it falls from around the tooth; in the lower jaw the saliva ejector can be employed. Bags made of bladder tissue may be used, but as these confine the water as it is formed, they are not so effective, although in the mouth the absence of dripping is certainly a convenience.

The following account, given by Dr. Cheize,[1] of a simple and successful method of obtaining local anæsthesia with ether is not without interest, inasmuch as the process might, in an emergency, be applied in dental practice:

"Several days ago a young girl presented herself with an ingrowing toe-nail, which she desired to have removed immediately, as she resided at a considerable distance. Richardson's apparatus not being available, I replaced it after the following fashion:

"I wet with ether a piece of wadding of about the size of a five-franc piece: this I placed upon the great toe, and with a chimney bellows blew a current of air upon the ether. In two minutes the evaporation was complete. I moistened the wadding a second time and evaporated as before. I then removed the ingrowing nail, and cauterized with a red-hot iron the internal border of the matrix without the slightest perception upon the part of the patient. I was obliged to show her the nail to convince her that the operation had been performed."

[1] See *Revue Odontologique de Bruxelles*, June, 1884.

ELECTRICITY.—Electricity is one of the many agencies which have been experimented with as pain-obtunders in tooth-extraction, both the galvanic and faradic currents having been employed and by several methods of application. Dr. J. O. Scott[1] states that he has employed the following method "with fair success:"

"Use a Kidder electro-magnetic machine, or any other giving very rapid vibrations of armature. Place the positive electrode on the gum of the tooth to be extracted, and the negative in the patient's hand or at the back of the neck. Start with a light current, and gradually increase the strength as much as can be borne without producing pain. The electrode applied to the tooth should embrace each side, the better to convey the current. For this purpose it should be bifurcated at the end of the handle, the arms of sufficient length for convenience in operating. At the ends of these solder small disks about the size of a dime. The handle and arms must be insulated, to prevent the current passing off at any other point than the disks. Cover the disks with thick pads of fine sponge. A cylinder electrode, also covered with sponge or cloth, is the proper one for the hand. Moisten each with saline water."

Another method was to attach one pole of the battery to the extracting forceps, the handles of which were carefully insulated, the other being held in the hand of the patient. Contact of the forceps with the tissues around the tooth of course closed the circuit, with the effect, usually, of giving an added pang to an already sufficiently painful process.

Concerning the general efficacy of this method the conclusions embodied in the following report of a committee of the College of Dentists, England, remain unquestioned:[2]

"The committee have in their possession the records of sixty-eight cases of tooth-extraction, in sixty-five of which the anæsthetic value of electricity was tested with all the care and the knowledge at the command of the observers. Fifty-five of these operations were performed to test the value of the intermittent current; ten were performed to test the value of the continuous current. In these experiments every possible modification was introduced. The poles of the battery were reversed in different cases; the force of the current, as indicated by the sensation of the patients, was varied; and every necessary precaution was taken to secure insulation of the operator.

"The committee, in viewing the whole of the results of the experiments thus performed, find that in much the larger proportion of cases the results were purely negative. In several instances more pain was excited, owing to the application of the current, than if the tooth had been removed at once by simple extraction, in other instances less, while in a few cases, amounting to five altogether, there was evidence of relief. In three instances this evidence was well marked.

"The committee does not, however, put forth these latter five named cases as instances of local anæsthesia. It appears to the committee that in all instances where success was apparent a mental element was called into action, and the patients at the time of the operation were in a state of partial general insensibility, due probably to hysterical syncope.

[1] See *Dental Cosmos*, May, 1881.

[2] *Ibid.*, October, 1859.

"In those examples where the patients expressed that the pain was less than they had experienced on previous occasions, the assumed relief did not arise from the fact that the tooth and its neighboring parts had been rendered dead to external impressions, but from various extraneous causes, of which the committee may enumerate as the most prominent—

"1. Diversion of sensation;

"2. Less difficulty in extraction as compared with other extractions;

"3. Syncope more or less marked;

"4. Differences in method of operating.

"On one final point the committee is unanimous: that in not one instance did any member observe the merest approach to local anæsthesia."

Voltaic Narcotism.—This term was applied by Dr. Richardson of London to his plan of local anæsthesia by the action of a galvanic current passing through a narcotic solution held in contact with the part to be operated upon, Dr. Richardson's claim being that under this influence narcotic substances passed much more readily into the tissues, and that in many instances complete local anæsthesia was in this way produced by solutions which were entirely inert when applied, even to the most delicate tissues, without the galvanic current.

In reference to the application of this plan to dental surgery the above-named committee report[1] that by the application of a narcotic solution to a tooth in connection with a continuous current of electricity of considerabte intensity, the pain of extraction is in some instances entirely broken, but that the process "can be used successfully only in cases where the cavity of the tooth is exposed." Dr. Richardson's plan never passed beyond the experimental stage, and the general verdict was, and remains, that any true anæsthetic influence produced by the method was due simply to the absorption of narcotic agents, upon the rate and efficacy of which process galvanism exercised no direct influence.

RAPID BREATHING.—This method of obtaining a transient analgesic influence was first suggested by Dr. W. G. A. Bonwill of Philadelphia, whose presentation of the merits of his discovery is here reproduced:[2]

"I can produce, from rapidly breathing common air at the rate of one hundred respirations a minute, a similar effect to that from ether, chloroform, and nitrous oxide gas in their primary stages; and I can in this way render patients sufficiently insensible to acute pain from any operation where the time consumed is not over from twenty to thirty seconds. While the special senses are in partial action the sense of pain is obtunded, and in many cases completely annulled, consciousness and general sensibility being preserved.

"To accomplish this, each patient must be instructed how to act and what to expeect. As simple as it may seem, there is a proper and consistent plan to enable you to reach full success. Before the patient commences to inhale he is informed of the fact that, while he will be unconscious of pain, he will know full or partially well every touch upon the person; that the inhalation must be vigorously kept up during the whole operation, without

[1] *Op cit.*

[2] "Rapid Breathing as a Pain-Obtunder," etc., by W. G. A. Bonwill, D. D. S., read before the Philadelphia County Medical Society, May 12, 1880; published in the *Scientific American Supplement*, No. 275, April 9, 1881.

for an instant stopping; that the more energetically and steadily he breathes the more perfect the effect; and that if he ceases breathing during the operation pain will be felt. Fully impress patients with this idea, for the very good reason that they may stop when in the midst of an operation and the fullest effects be lost. It is obligatory to do so on account of its evanescent effects, which demand that the patient be pushed by the operator's own energetic appeals to 'go on.' It is very difficult for any person to respire more than one hundred times to the minute, as he will become by that time so exhausted as not to be able to breathe at all, as is evidenced by all who have thus followed my directions. For the next minute following the completion of the operation the subject will not breathe more than once or twice. Very few have force enough left to raise hand or foot. The voluntary muscles have nearly all been subjugated and overcome by the undue effort at forced inhalation of one hundred over seventeen, the normal standard.

"The heart's action is not increased more than from seventy (the average) to eighty, and sometimes ninety, but is much enfeebled or throwing a lesser quantity of blood. The face becomes suffused, as in blowing a fire or in stooping, which continues until the breathing is suspended, when the face becomes paler. (Have not noticed any purple, as from asphyxia by a deprivation of oxygen.) The vision becomes darkened, and a giddiness soon appears. The voluntary muscles farthest from the heart seem first to be affected, and the feet and hands, particularly the latter, have a numbness at their extremities which increases, until in many cases there is partial paralysis as far as the elbow, while the limbs become fixed. The hands are so thoroughly affected that when open the patient is powerless to close them, and *vice versâ*. There is a vacant gaze from the eyes, and a looking into space without blinking of the eyelids for a minute or more. The head seems incapable of being held erect, and there is no movement of the arms or legs, as is usual when in great pain. There is no disposition on the part of the patient to take hold of the operator's hand or interfere with the operation."

Dr. Bonwill's theory of the action of rapid breathing in producing insensibility to pain is thus summed up:

"The *first* thing enlisted is the *diversion of the will-force* in the act of forced respiration at a moment when the heart and lungs have been in normal reciprocal action (twenty respirations to eighty pulsations); which act could not be made and carried up to one hundred respirations per minute without such concentrated effort that ordinary pain could make no impression upon the brain while this abstraction is kept up.

"*Second*. There is a specific effect resulting from enforced respiration of one hundred to the minute due to the *excess of carbonic acid gas set free from the tissues*, generated by this enforced normal act of throwing into the lungs *five times* the normal amount of oxygen demanded in one minute, when the heart has not been aroused to exalted action, which comes from violent exercise in running or where one is suddenly startled; which excess of carbonic acid cannot escape in the same ratio from the lungs, since the heart does not respond to the proportionate overaction of the lungs.

"*Third*. Hyperæmia is the last in this chain of effects, which is due to the excessive amount of air passing into the lungs, preventing but little more than the normal quantity of blood from passing from the heart into the arterial circulation, but damming it up in the brain, as well as throughout the capillary and venous system, and as well upon the heart, the same as if it were suspended in that gas outside the body."

Dr. Addinell Hewson of Philadelphia, who has extensively and successfully employed the rapid-breathing process in minor surgical operations, gives the following account of the phenomena incident to the process as he has observed them:

"The first effect of this breathing appreciable to an observer is a change in the color of the face: the lips, the cheeks, and the tint of the face, at first brightened, generally become pallid, then leaden or bluish; and with these latter changes the expression is altered and wanting in animation. If the eyes are open, they have a vacant look, and the lids begin to droop; the patient assumes the look of one much overcome by fatigue, and then of one on the verge of an ordinary sleep. Then often ensues, especially in an hysterical young girl, a state of very positive muscular rigidity: before this, however, ensues, the state of analgesia has been brought about, and is indicated by the want of recognition of the prickings of pins or the like, for the patient will always feel the abrupt contact of obtuse bodies, even the touch of your hand, but will not now experience any pain even from a bistoury or scalpel. The state of rigidity which I have just referred to resembles much that of catalepsy and what is frequently noticeable in cases where anæsthetics are being administered. The power to move is embarrassed by this; the will, however, would seem to have persisted, as the patients tell you afterward, and may even show you during this state by their efforts, without full ability, to follow your directions in moving or suffering you to move a limb. This rigidity of the muscular system is by no means of constant occurrence; it is often very slight and transient and gives way. It is clearly from the semi-asphyxiated state induced by the patient's breathing, for on ceasing to urge on him the rapid rate, he relapses into a quiet normal rate, and so, soon allowing his blood to recover from its intensely purple hue, he comes out of this state, and gradually recovers his ability to appreciate and remember the contact of foreign bodies and to move away from them.

"The subjective phenomena of this process are, as far as they go, essentially like those from nitrous oxide, ether, and even chloroform. There is first the swimming or confusion in the head and the loss of perfect or acute consciousness, attended with a sensation of tingling and distension of the surface; this latter beginning at the sentient extremities, and the hands especially, and passing upward; and closely following these sensations comes the condition of analgesia, absence of appreciation of painful impressions on those sentient nerves. . . . .

"Every circumstance would therefore seem to indicate that this process of inducing insensibility to pain is one essentially of diminished oxidation and decarbonization of the blood, and, recognizing such a state as belonging to the initiative stage of all anæsthetics when *insensibility to pain* is positively marked, we have no necessity for begging any special theory for this process, as in its action it readily comes under the category of such agents, and is thus not either an *absurdity* or an impossibility from a scientific point of view."[1]

It will be observed that while Dr. Bonwill and Dr. Hewson perfectly

[1] "Some Comments on the History of Nitrous Oxide Gas as an Anæsthetic, and on the Analgesic Effects of Rapid Breathing," by Addinell Hewson, M. D. From the *Trans. International Medical Congress*, Philadelphia, 1876.

agree as to the efficacy of the process, they radically differ as to the nature of the physiological changes in the nervous, respiratory, and circulatory systems produced during its progress. Further investigation upon these points would seem to be needed, as none of the theories yet advanced fully and satisfactorily explain the phenomena in question.

The process itself has as yet come into but limited use, although Dr. Bonwill in his own practice (dental) uses it to the exclusion of all other agencies.

For the production of satisfactory results the method would appear to demand from the patient a violence of exertion of which many are quite incapable, and which is not without its dangers for aged persons or for those affected with cardiac lesions or with structural degeneracy of the arterial walls, or in whom there exist pathological conditions of the respiratory tract.

If, however, by the judicious practice of this method an expectancy of painlessness can be secured, and the courage of the patient be thus so fortified that he will consent to the performance of slight operations without resort to general anæsthesia, a great good will have been accomplished, even though the expectancy should prove more or less illusory.

As regards the extraction of teeth, the fact must be remembered that, when skilfully accomplished, the operation, while never agreeable, is in a considerable percentage of cases almost painless. In such cases at least the operator should discourage the use of anæsthetics and adopt any legitimate method to induce his patient to submit to the operation without their aid. In that vastly greater class of cases, however, in which it is certain that for the patient in the normal state the suffering incident to the surgical procedure will be very severe, simple humanity demands the adoption of alleviatory measures; and of these analgesia by rapid breathing is not likely soon or readily to supplant the use either of local anæsthetics or of agents which swiftly and surely bestow not only absolute painlessness but oblivion.