Quick Study® ACADEMIC

BIOLOGY 2

Featuring: Evolution/origins, molecular biology, cancer biology, human aging and immunology

Evolution

A. **Definitions**
1. Concept that all organisms are related by common ancestry
2. Fundamental paradigm of biology

B. **Natural selection:** The mechanism for how evolution occurs
1. Species have high potential for rapid reproduction
2. Population sizes eventually level off and remain fairly constant over time
3. There is **competition** for reproduction and survival of offspring
4. **Variations** (from random **mutations** and shuffling of genes via **meiosis**) exist in behavior, physiology, structure, etc.
5. Nature selects individuals (i.e., the **fittest** or just fortunate) for survival and reproduction to pass these favorable characteristics (**adaptations**) via their genes to their offspring
6. Over time, natural selection "can" lead to genetic changes in populations – i.e., evolution
7. **Microevolution:** Small-scale changes
8. **Macroevolution:** Larger-scale changes; can lead to evolution of new species and groups

Cellular/Molecular Evidence for Evolution

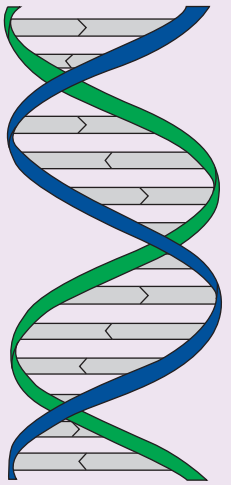
A. **Cell Theory**
1. The cell is the basic unit of life
2. Every life form, from bacteria to humans, is made of/comes from this basic structure

B. **Organic Molecules**
1. 99% of all life consists of carbon, hydrogen, oxygen, nitrogen, phosphorus and sulfur
2. Evolutionary relatedness explains organisms' common usage of a small subset of over 90 available elements

C. **DNA**
1. Genetic, informational molecule in every organism, including viruses (which appear to be molecular fragments of DNA/RNA capable of "living" in host cells)
2. DNA "language" (**genetic code**) is essentially universal (slightly different dialects exist in some single-celled organisms and in some mitochondrial/chloroplast **genomes**)
3. A common genetic language allows for such phenomena as the insertion of human genes into bacteria, which can then produce "human" proteins (see **Molecular Biology**)

D. **ATP** (Adenosine triphosphate): The primary energy currency molecule used by every organism

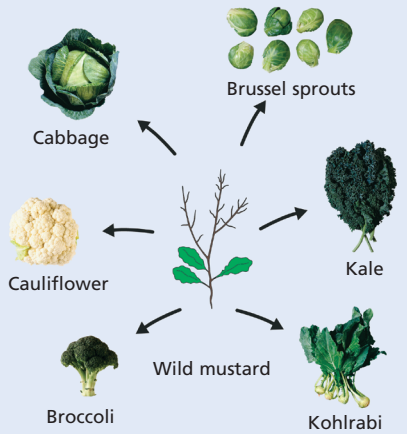
DNA Double Helix



Evidence for Evolution via Natural Selection

A. **Artificial selection**
1. Human-controlled breeding of species strongly supports the idea that, over time, nature could also influence changes in populations
2. Humans have selected for traits to increase the attractiveness (to us) of the offspring (e.g., "cute" dogs, chickens that produce many eggs, wheat that yields numerous, plump grains)
3. Domesticated species often do poorly in the wild, as traits (i.e., variations) selected by humans would not necessarily be advantageous in nature

Artificial Selection For Crop Production

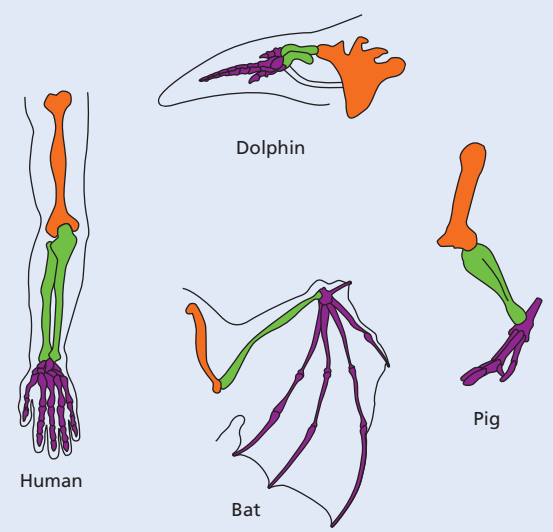


B. **Biogeography:** Geographic distribution of species can show organisms are related
1. Flightless birds, such as African ostriches, Australian emus, and South American rheas are found (naturally) only in the southern hemisphere; on separate continents
2. Either flightlessness in these birds evolved independently three times (possible, but improbable) or they arose from a common, flightless ancestor
3. If the latter explanation is correct, and they could not fly, how then could they get to these disparate southern continents while being excluded from the northern hemisphere?
4. Geological evidence indicates the continents were once one large land mass that subsequently broke up into pieces (**plate tectonics**) that moved (**continental drift**) first into northern and southern portions, and later into the present-day continents
5. This geological concept also explains why **marsupial mammals** (e.g., kangaroos) developed only on Australia, as this continent was geographically isolated from areas where **placental mammals** evolved

C. **Fossils**
1. Preserved remnants of dead organisms
2. Darwin termed evolution "**descent with modification**"
3. Although the fossil record has gaps (some structures/organisms do not fossilize well), fossils provide valuable information about evolutionary changes or modifications in organisms (including transitional forms, e.g., horses with toes, whales with hind limbs, ferns with seeds) that have taken place over many generations
4. Estimating the age of fossils involves looking at their physical positions in sedimentary rocks (**relative dating**) and radiometric isotope techniques (**absolute dating**)
5. **Molecular clocks** look at changes in portions of genomes of organisms; also used to help determine the age of evolutionary events

D. **Homologies**
1. Anatomical similarities of related life forms
2. Provide strong evolutionary evidence of relatedness
3. Example: Forelimbs of vertebrates are composed of the same basic bones in disparate groups, but differ based on adaptations necessary for the specific environmental needs (i.e., walking, swimming, flying)
4. **Vestigial structures**
   a. Those present are usually in a rudimentary, non-functional form
   b. Show anatomically-related structures that are likely to disappear completely in future generations
   c. Example: The vestiges of pelvic bones within the body in some modern-day baleen whales

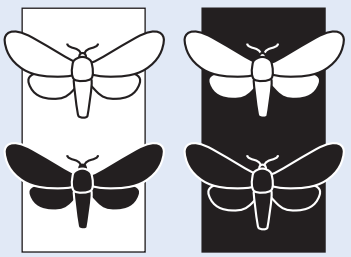
Homologous Forelimb Bones: Evidence for Vertebrate Evolution



Evidence for Evolution via Natural Selection cont.

E. **Variations in Life**
1. In England, the peppered moth shifted from predominantly light coloring to dark when air pollution darkened the trees on which it lives
2. Predators can easily spot moths that contrast with their background, limiting the abundance of these types of moths in the population
3. Subsequent air quality measures have lightened trees and light-colored moths are again the predominant form
4. Additional examples of selection observed in living organisms involve increasing drug resistance: e.g., bacteria-antibiotics, insect-insecticides and HIV-drug therapies

Generations of Peppered Moths Changed Color to Match Habitat



Human Origins

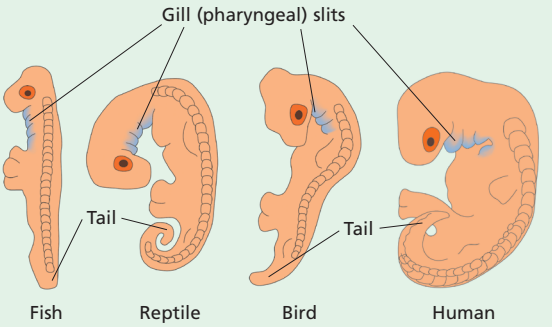
A. Where do humans fit in the evolutionary scheme?

B. Some of the greatest evidence for evolution is seen when comparing vertebrate chordates, which include humans (see **Homologies,** Evolution & Natural Selection)

C. **Comparative anatomy of adults**
1. Obvious visual similarities in adult vertebrates (i.e., eyes, ears, mouth, nose, appendages) link humans to other vertebrates, especially the great apes

D. **Comparative embryology**
1. **Earnst Haeckel** coined the phrase "ontogeny recapitulates phylogeny," suggesting the false claim humans start as fish, then progress through a series of developmental stages that retrace the lower vertebrate groups before becoming human
2. Early developmental stages of humans share remarkably similar vertebrate characteristics that either disappear or become vestigial in adult humans
   a. **Gill (pharyngeal) slits** (they occasionally do not close in infants – **cervical (branchial) fistulae** – may require surgery)

Embryonic Similarities Among Vertebrates



E. **Vestigial structures**
1. Show clear links to vertebrate ancestry and include the following non-functional structures:
   a. **Tail bones (coccyx)**
   b. **Ear muscles** (function in other mammals)
   c. **Nictitating membrane** (3rd eyelid in some vertebrates)
   d. **Pointed canine teeth**

(continued pg.3)

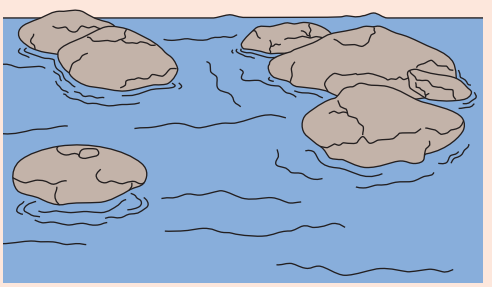
Origins of Life

A. The ultimate spark of life may never be known but science provides a controversial scenario of how life "might" have arisen

B. **Universe/Earth origins**
1. First, the universe had to be formed, theoretically via the **Big Bang** about 16-18 billion years ago
2. Geologic and other physical evidence date the earth's origin to about 4.6 billion years ago
3. The crust and **biosphere** (thin portion of earth where life exists) would not be habitable (too hot) for nearly a billion years

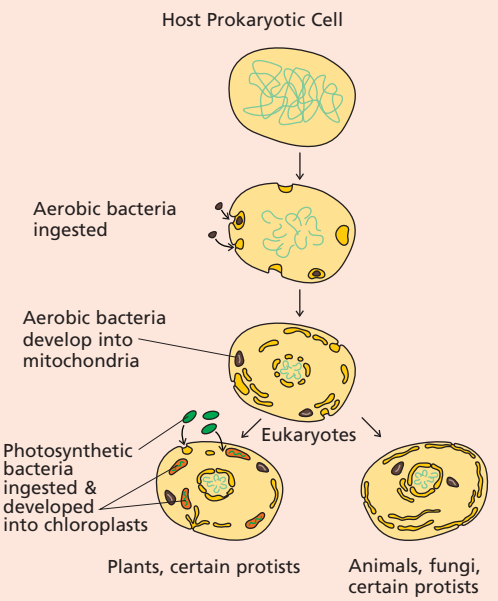
C. **First cells**: How did they form?
1. Early hypotheses suggest life arose spontaneously from simple molecules (e.g., CO, CO_2, N_2, H_2O) that combined into larger, complex macromolecules such as proteins, carbohydrates, lipids and nucleic acids
2. Some rocks from outer space (meteorites) have pre-formed complex organic molecules, including the five nitrogenous bases that make up DNA/RNA
3. Whether life was seeded from outer space (**panspermia**), or macromolecules were synthesized entirely on earth, the next step was to incorporate these organics into cells – the basic functional units of life
4. These first life forms were likely **heterotrophs**, which consumed the abundant food molecules present in the "**primordial soup**"
5. Later, photosynthesis (by **autotrophs**) developed and oxygen levels began increasing in the atmosphere
6. The oldest fossils discovered (aged 3.8 billion years) consist of photosynthesizing bacteria called **stromatolites**, which still have representatives in colonies that form large, calcareous structures in some shallow, tropical oceans

Stromatolites Form Aquatic Reefs



D. **Oxygen crisis and the endosymbiotic hypothesis**
1. Geologic evidence supports increasing oxygen levels via photosynthesis-created "rust" zones at similar ages in ancient sea beds worldwide
2. Chemically, oxygen is a corrosive element to organic molecules as well, and likely created a crisis for many of the earliest life forms
3. Some bacteria evolved a metabolic pathway that could neutralize as well as produce ATP energy from this highly-reactive oxygen
4. Symbioses formed between these oxygen-consuming, energy-producing bacteria and other larger, soft-bodied bacteria that lacked protection against the effects of oxygen
5. This was the birth of the **eukaryotic** cell, from **prokaryotic** ancestors; one of the major evolutionary events in life
6. This **endosymbiotic hypothesis** is supported by the following facts:
   i. **Mitochondria** (use oxygen for metabolism) have their own set of DNA, separate from that of the cell nucleus
   ii. **Mitochondrial DNA** is more like present-day bacterial DNA than the **nuclear DNA** of the cell in which it resides
   iii. **Chloroplasts** have their own genomes
   iv. Today, living organisms provide numerous examples of symbiotic relationships between single-celled organisms; sometimes including bacteria that perform the role of mitochondria in cells lacking ATP-producing organelles
7. Eukaryotic cells subsequently evolved into protists, fungi, plants and animals
8. Prokaryotes continued to thrive and, though microscopic, are among the most successful groups of organisms on earth

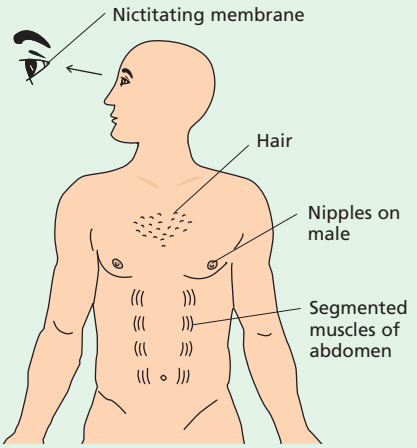
Evolution of Eukaryotic Cells



Human Origins

e. **3rd molar teeth**
f. **Hair** (plays major thermoregulation role in most mammals)
g. **Nipples in males**
h. **Appendix** (functions as digestive caecum in many mammals)
i. **Segmented muscles of abdomen**
j. **Pyramidalis muscle** (absent in 20% of humans; arguably unnecessary; present in other mammals)

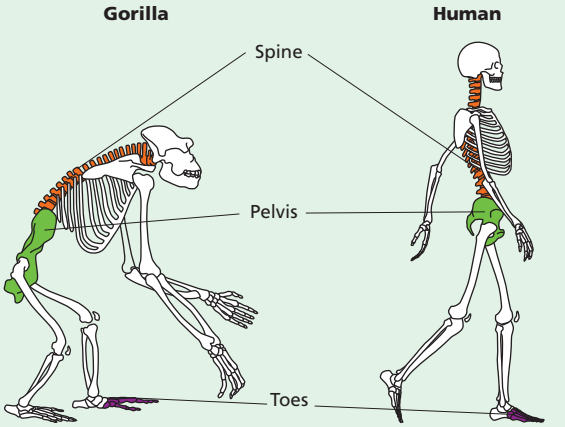
Some Vestigial Structures in Humans



F. **Molecular Comparisons**
1. Comparison of DNA sequences in humans and chimpanzees show average similarity of 98.5%
2. Comparison of hemoglobin amino acid sequences (the main carrier of oxygen in the blood of thousands of different animals [by itself evidence for evolution]) between humans and other vertebrates show the same evolutionary patterns as those with skeletal/physical anatomy that is comparative, with the great apes showing the greatest similarity

G. **Fossil Record**
1. Fossils show a transition from ape-like forms to the first primitive human forms that were truly **bipedal** (walking on the pelvic appendages or legs)
2. Modern apes are not bipedal, but one of the oldest fossil forms (3.2 million years) resembling an ape to walk bipedally was named ***Australopithecus afarenesis*** or Lucy (named after a famous Beatles song)
3. From this origin in Africa, modern humans, ***Homo sapiens***, eventually arose
4. Debate exists among paleoanthropologists about how to arrange the phylogenetic tree of humans based on the available fossils
5. Most agree that Neanderthals were the most recent group of humans to become extinct, and were probably a subspecies called ***Homo sapiens neanderthalensis***
6. From these origins, humans have spread to most land areas on Earth

Anthropoid Skeletal Comparison



Molecular Biology

A. The discovery that DNA is the informational molecule housing genes started a revolution in biology

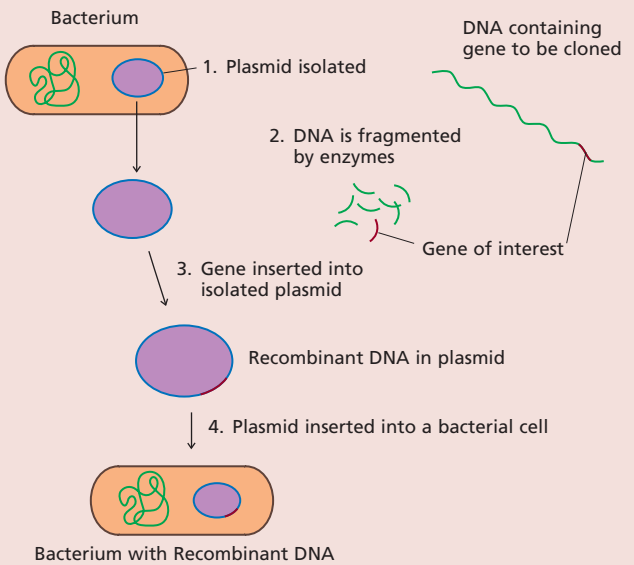
B. **Molecular biotechnology** is now a pervasive component in modern societies

Cloning

A. **Gene Cloning**

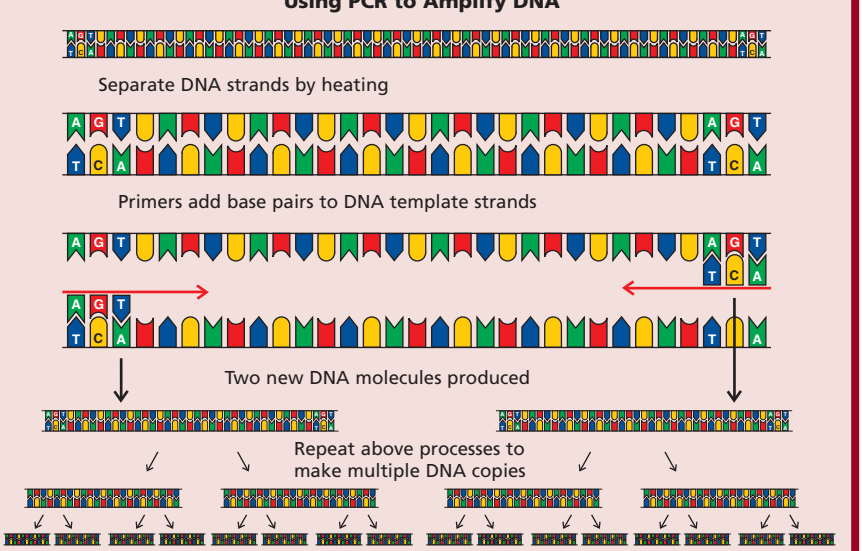
1. Making exact copies of genes
2. Involves two major processes:
   a. **Recombinant DNA**
      i. **Restriction enzymes** create DNA fragments with the gene of interest
      ii. DNA fragments are fused with DNA from a bacterium (**plasmid**)
      iii. Newly-created **recombinant DNA** is placed into bacteria
      iv. Bacteria produce protein for which the "cloned" gene coded
      v. Large quantities of the gene, and thus protein, are produced as the bacterial cell reproduces

Gene Cloning using Recombinant DNA



b. **Polymerase Chain Reaction (PCR)**
   i. Amplifies (copies) a segment of DNA without using a bacterial (or other) host organism
   ii. DNA sample is heated until the double helix denatures (hydrogen bonds are broken), separating the DNA into two single strands
   iii. Heat-resistant, single-stranded DNA primers allow DNA polymerase to add the appropriate nucleotides to each side of the separated DNA strands
   iv. This process results in multiple copies of the original DNA
   v. Repeating the process on the copies, via automation, can amplify a small DNA fraction a billion fold in a short period of time

Using PCR to Amplify DNA

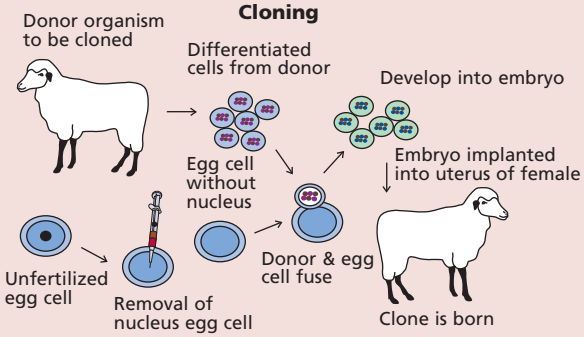


B. **Reproductive cloning**
1. Produces living cells/organisms with exactly the same DNA in the nuclei as that from a donor cell/organism
2. Specifically, DNA from the nucleus of a **somatic cell** of the donor is inserted into an **egg cell** from which the original nucleus has been removed
3. The new egg cell is electrically or chemically stimulated to begin cell division and embryonic development
4. The growing embryo is implanted into a female where development continues until birth

Molecular Biology cont.

5. The new individual is not a true clone of the donor organism, as the mitochondrial DNA is from the organism that donated the egg
6. Survival rates have been low as multiple factors (mostly unknown) influence successful development, such as source of donor cells

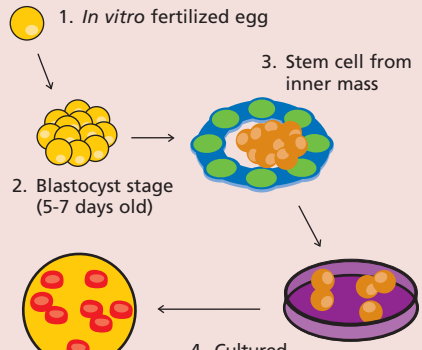
Cloning



C. **Therapeutic cloning**

1. Use of reproductive cloning to create human embryos to procure **stem cells,** which have potential to develop into adult tissues
2. These special cells may hold the key to treatments for many diseases (heart, cancers, Alzheimer's, Parkinson's) and afflictions (injury to spinal cord, including paralysis)
3. Stem cells can also be retrieved from human embryos produced by regular fertilization processes (***in vivo*** or ***in vitro***) or adults (e.g., bone marrow)
4. Stem cell procurement via cloning and embryos is a growing ethical and political issue

Culturing Stem Cells



Genomics

A. Study of the structural and functional aspects of the entire set of genes in a species (i.e., genome)

B. Encompasses many different aspects of approach

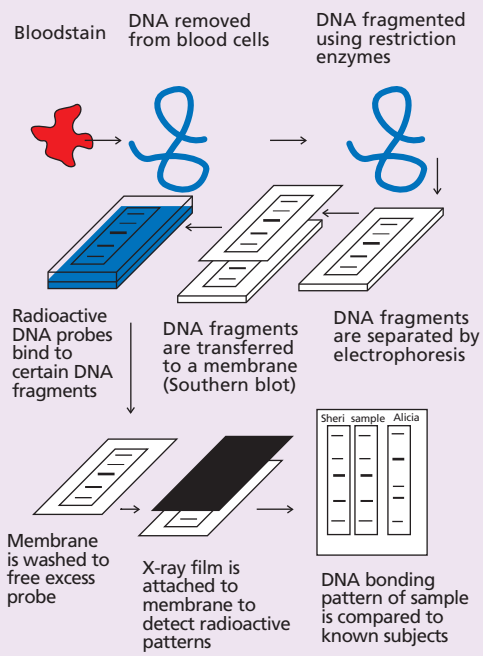
1. **Bioinformatics** uses computer/statistical applications to access large databases concerning DNA/gene/protein information
2. **Proteomics** studies the functioning of the proteins coded by the genes

C. Several specific applications of genomics will be discussed further below:

1. **Restriction Fragment Length Polymorphisms (RFLP)**
   a. Technique relies on enzymes discovered that protect bacteria from "foreign" DNA of bacteriophages (viruses specific for bacteria) and other invading bacteria
   b. These bacterial restriction enzymes cut foreign DNA at specific points or **restriction sites**, while protecting their own DNA by adding special "buffering" functional groups to potentially susceptible areas
   c. Exact positions of restriction points are highly individual, reproducible and measurable
   d. DNA samples from the same individual will produce the same fragments, but these fragments will be different from others (polymorphic)
   e. Fragment patterns can be represented visually as a **DNA fingerprint**, by use of special electrophoretic processes
   f. RFLP is used frequently in forensic, criminal and paternity applications
   g. Because DNA samples may be minute in some of these applications, PCR amplification may be used to create quantities necessary for RFLP analysis
   h. A modified DNA fingerprint approach has been developed using polymorphisms of **satellite (repetitive) DNA** regions called **Simple Tandem Repeats (STR)**

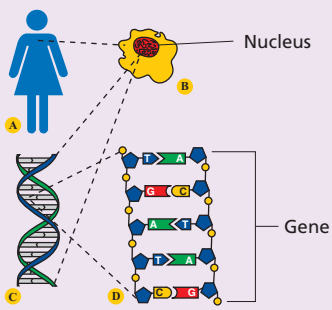
2. **Human genome project**
   a. Monumental, historical effort to determine the actual sequence of the entire set of chromosomes in humans - **gene mapping**

DNA fingerprinting using RFLP



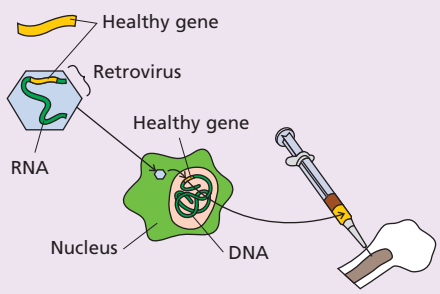
   b. Involved over 3 billion base pairs, which if written, would create a book with a half-billion pages and take nearly a lifetime to read
   c. Several molecular techniques were employed, with automated computer-assisted analysis paving the way for a rapid conclusion to the project
   d. Although the precise number of genes is still unknown, *a priori* estimates suggested there would be nearly 100,000
   e. Actual number probably does not exceed 40,000, which when compared to simpler organisms suggests human genomics is extremely concise, but complex
   f. Future studies will undoubtedly reveal much about how genes function, which should lead to numerous future benefits

Genomic Project-Mapped Human Genes



3. **Gene therapy**
   a. Treating diseases and injury in humans involves the use of harmless retrovirus vectors (or other entry mechanisms) that possess the enzyme **reverse transcriptase**, allowing them to insert genetic information "into" DNA
   b. Normal information flow occurs "from" the DNA
   c. These treatments raise ethical questions, but certainly have tremendous potential
   d. Limited success and legal restrictions using human subjects have made progress in this area challenging

Using Retroviruses to Insert Healthy Genes



4. **Genetic engineering**
   a. Research involving gene transfer in non-human organisms has been much more extensive
   b. **Transgenic** and **genetically-modified** plants and animals are becoming more common
   c. Great potential to artificially select desirable traits in crops, farm animals, etc.
   d. Safety concerns are still high as this new technology is incorporated into modern society

Biology of Cancer

Optional review: "*Cell Reproduction" section, p.2 of* ***Quickstudy***® **Biology** *guide*

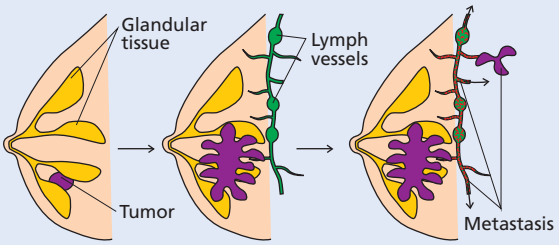
A. Cells reproduce by dividing primarily through two processes:
   1. **Mitosis:** Nuclear division
   2. **Cytokinesis:** Cytoplasm division

B. Cell division is part of the **cell cycle**, which is under a control system involving internal and external factors

C. **Cancer cells** have escaped this regulatory process through **transformation** and divide uncontrollably

D. **Tumors** form, which may progress from a **benign** to a **malignant** state and interfere with normal tissue functioning

Tumor Formation & Spreading

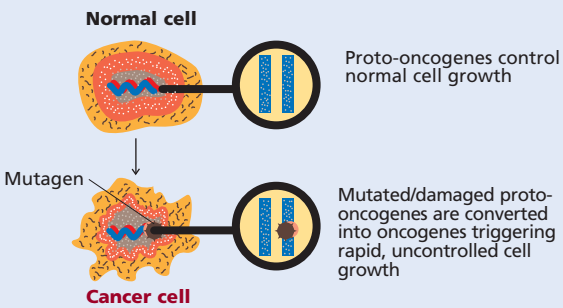


1. Malignant tumor starts from single cancerous cell
2. Tumor grows, invading neighboring tissue
3. Lymph and blood vessels spread cancer cells to other areas of the body

E. **Metastasize:** Initial tumor cells can spread and form more malignant tumors in other tissues in the body

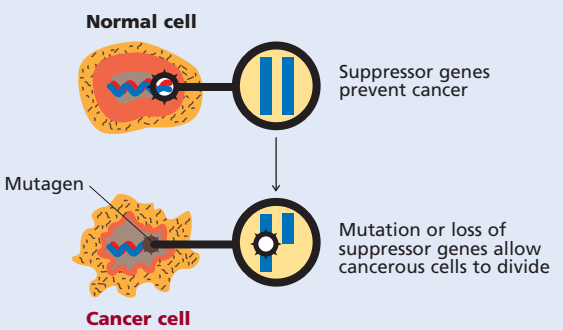
F. **Oncogenes** stimulate abnormal cell growth and division, which can lead to malignant tumors
   1. These abnormal genes are converted from normal genes (**proto-oncogenes**) that regulate the cell cycle. Viruses can also deliver oncogenes to cells

Oncogene Activation Leading to Cancer



G. **Tumor-suppressor genes** normally prevent the uncontrolled growth and division of cells and tissues

Tumor-Suppressor Gene Deactivation Leading to Cancer



H. **Mutations** are primary factors contributing to cancers
   1. **Mutagens** are any factors that can trigger mutations – those that cause cancer are called **carcinogens**

I. All tissues in the human body are susceptible to tumors, because mutations (either induced by carcinogens or **inherited**) can occur in any cell

J. Cancers are prevalent and difficult to cure (in most cases) because of our limited knowledge about:
   1. Factors controlling the cell cycle
   2. The genomics of humans

Biology of Aging

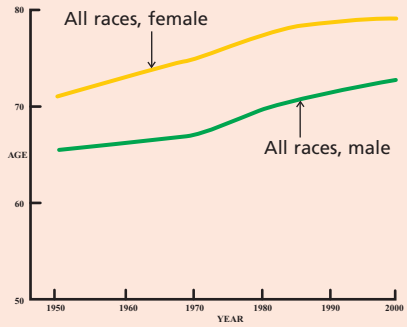
A. Most animals in nature die shortly after their reproductive years, and in some cases, die immediately after reproduction

B. Humans and most animals kept under controlled conditions can survive many years after fertility has waned, allowing the phenomenon of aging to be studied

C. For humans, the potential to live longer has been realized over our history; in the last 50 years, average lifespan in well-developed countries has risen from the 60-70s to nearly 80 years

D. Considering the longevity of some rare individuals, human lifespan could be up to 120-130 years in the near future

Human Lifespan Increase



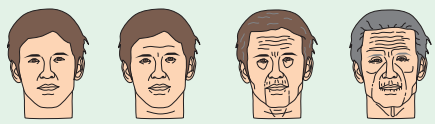
Theories of Aging

A. What prevents all but a few of us from living to our physiological maximum?

B. What are the specific causes for the physical transformations that occur as we age?

C. **Random events** may accumulate and contribute to early senescence; some specific hypotheses follow:
   1. **Free radical** formation typically involves the production of oxidative metabolic by-products such as molecular variants of oxygen, which may damage the DNA, RNA, proteins and mitochondria
      a. Anti-oxidants produced naturally may eventually lose the battle in cells, causing cell death
      b. Proponents of this hypothesis suggest supplemental intake of anti-oxidants (e.g., found in vitamins) may slow this form of damage
   2. **Cross-linking** suggests as cells age, structural molecules such as DNA and proteins form unsuitable attachments within or between other molecules
      a. Skin wrinkling, cataracts of the eye, atherosclerosis in blood vessels, kidney function and brain function decline are all possibly related to cross-linking
      b. Some drugs that prevent or slow cross-linking may be important future therapies

Physical Changes During Aging



   3. **Wear and tear** suggests that the mere use of cells and concomitant damage result in aging
      a. This type of damage occurs at the DNA level, which has its own set of repair proteins
      b. Years of exposure to mutagens such as toxins and various forms of radiation are not always repaired
      c. At the ends of DNA molecules are protective caps called **telomeres**, which are degraded with each cell division event
         i. Telomere loss eventually can lead to DNA damage
         ii. Telomerase, an enzyme that repairs these end caps, has been shown to keep cells in a more "youthful" state
   4. **Somatic mutations**, those occurring in tissues outside of the egg or sperm, could lead to diminished function; skin and connective tissues lose resiliency, muscles become weaker, brain cells become less efficient, etc.
   5. **Rate of living hypothesis:** Suggests those that "live the fastest, die the youngest"
      a. Theorizes those organisms with the most active metabolisms have the shortest lifespan
      b. With mammals, this is usually the case (e.g., an elephant lives longer than a mouse)
      c. Hypothesis may be broadly linked to those under the pre-programmed events (see below)

D. **Pre-programmed events** may be a cause of senescence in humans; following is a discussion of specific hypotheses:
   1. **Genetic theory** suggests our lifespan is determined by the inherited genes
      a. When food and health issues are maintained at least minimally, humans have roughly the same lifespan
      b. Females in most instances (including other animals) typically live longer than males
      c. Offspring of long-lived parents typically live longer than offspring of shorter-lived parents
      d. The above observations strongly suggest at least part of lifespan determination is related to **longevity-assurance genes**
   2. **Pacemaker theory** suggests there are "**biological clocks**" or **pacemakers** that commence at birth and simply slow and stop, ending in death
      a. Specifically, the immune and neuroendocrine systems are thought to be controlled by pacemakers
      b. Cessation of these systems could account for body-wide failures, susceptibility to attack by foreign agents, and increase incidence of cancers

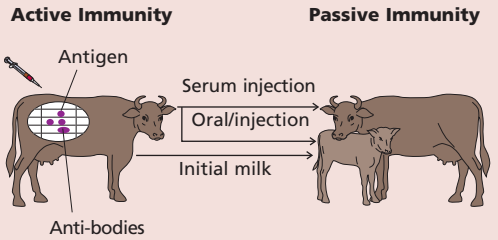
Immunology

Optional review: "*Immunology" section, p.5 of* ***Quickstudy®*** **Physiology** *guide*

A. The body has two main lines of defense against injury and infection:
   1. **Nonspecific immunity** involves a generalized, similar response to a wide variety of potentially harmful conditions; a typical component of this response is **inflammation**, which results in swelling, redness, heat and pain in the affected area
   2. **Specific immunity** is an extremely specific response typically involving the production of **antibodies**, which are designed with the exact purpose of combining with specific cell surface markers, or **antigens**, of foreign agents (microbes, toxins)

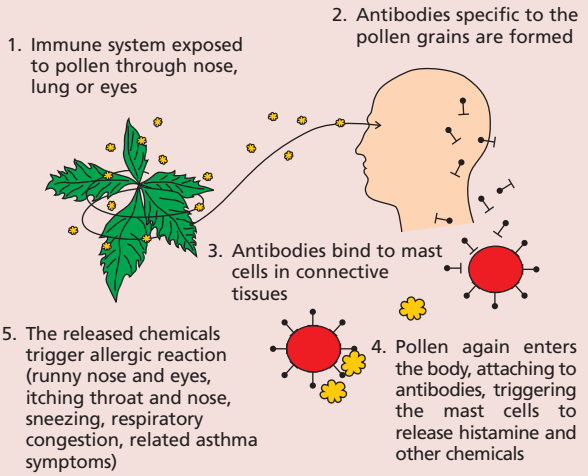
B. Selected subjects related to immunity are discussed below:
   1. **Passive immunity** involves receiving antibodies or antiserum from another source
      a. This could involve maternal antibody delivery to the fetus/child via breast milk from the mother or injections (also for treatment of venomous bites/stings)

Antibodies Injected or Passed to Others



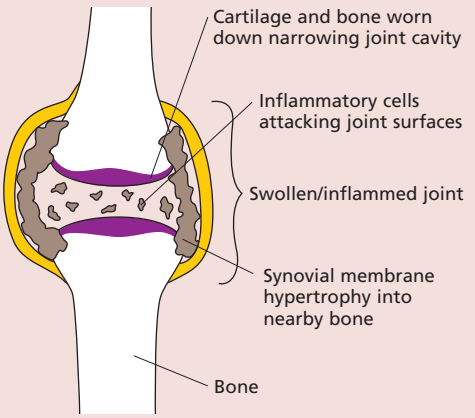
   2. **Vaccinations** contain weakened versions of pathogens injected into the body to stimulate, among other aspects of specific immunity, B cells to produce two products:
      a. **Plasma cells**, which begin synthesizing antibodies within 10-17 days
      b. **Memory cells**, which retain the potential (for up to many years) to develop quickly (within 2-5 days) into antibody-producing plasma cells upon subsequent exposure
      c. This quicker response could mean the difference between successfully destroying the foreign antigen versus possible death of the individual

Allergic Reaction Events



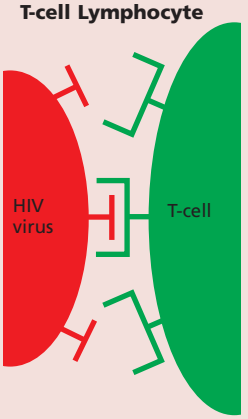
   3. **Allergies** are hypersensitive tissue reactions to part of the specific immune response
      a. Specifically, antibodies against specific antigens called **allergens** trigger tissue response resulting in typical allergic symptoms (e.g., hay fever, asthma)
      b. Severe allergic reactions can lead to **anaphylactic shock**, which may be life-threatening
   4. **Autoimmunity** is a condition in which cells of the specific immune response attack healthy tissues
      a. Normally, those antibodies and cells of the immune response that could harm "self" tissues are either suppressed or deleted to prevent such self attacks
      b. The following diseases/afflictions are triggered or related to autoimmunity:
         i. Rheumatoid arthritis
         ii. Diabetes mellitus
         iii. Grave's disease
         iv. Multiple sclerosis
         v. Lupus

Autoimmune Disease Leading to Rheumatoid Arthritis



   5. **Immunodeficiency diseases** are those in which some aspect of the immune system (usually specific) is defective, thus compromising the ability of the body to protect itself
      a. One of the best known of these is **Acquired Immunodeficiency Syndrome (AIDS)** - a disease which is triggered by the **Human Immunodeficiency Virus (HIV)**

HIV Virus Attacking Helper T-cell Lymphocyte



      i. In this affliction, the virus attacks immune cells called helper T cells, which are integral in mounting a specific immune response
      ii. Individuals with such compromised immune systems are susceptible to secondary infections and cancers, which untreated usually leads to death
      iii. AIDS is still a worldwide health issue and the leading cause of premature death in some countries
   b. **Severe Combined Immunodeficiency Syndrome (SCIDS)** is a rare congenital condition in which T and B cells are defective
      i. In the most severe cases, a person is born essentially with no specific immune response and stands little chance of warding off infection
      ii. Death can occur within the first year without a bone marrow or stem-cell transplant
   6. **Bacterial resistance to antibiotics** can occur when medical drugs are used to supplement the specific immune response, the latter of which may be too slow to prevent serious and possibly fatal symptoms
      i. When antibiotics are taken, highly resistant forms of bacteria may survive and reproduce
      ii. These new "resistant" strains may be extremely difficult, if not impossible, to treat
      iii. Over-prescribing of antibiotics may be a leading cause of resistance
      iv. As much as half of the roughly 100 million prescriptions for antibiotics written each year may be unnecessary (e.g., colds and flu symptoms are caused by viral infections; therefore, antibiotics are of limited use)
      v. When prescriptions are given, medication should be taken to completion - only taking a portion of the pills may allow the hardiest bacteria to survive and evolve

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Author: Randy Brooks, PhD