The chemistry of living things

1. ~~**All matter consists of elements**~~

    ~~**Atoms are the smallest functional units of an element**~~

    ~~**Isotopes have a different number of neutrons**~~

2. Atoms combine to form molecules

~~**Energy flues life's activities**~~

Chemical bonds link atoms to form molecules

Element	Atomic symbol	Functions in life
Oxygen	O	Part of water and most organic molecules; also molecular oxygen
Carbon	C	The backbone of all organic molecules
Hydrogen	H	Part of all organic molecules and of water
Nitrogen	N	Component of proteins and nucleic acids
Calcium	Ca	Constituent of bone; also essential for the action of nerves and muscles
Phosphorus	P	Part of cell membranes and of energy storage molecules; also a constituent of bone
Potassium	K	Important in nerve action
Sulfur	S	Structural component of most proteins
Sodium	Na	The primary ion in body fluids, also important for nerve action
Chlorine	Cl	Component of digestive acid; also a major ion in body fluids
Magnesium	Mg	Important for the action of certain enzymes and for muscle contraction
Iron	Fe	A constituent of hemoglobin, the oxygen-carrying molecule

3. Life depends on water

- Accounts for 60% of your body weight.
- Important properties of water
  - Water molecules are polar
  - Water is a liquid at body temperature
  - Water can absorb and hold heat energy

    → these properties make water an ideal solvent and an important factor in temperature regulation.

> - The polar nature of the water molecule accounts for its physical properties and for its unusually good qualities as a solvent for most other molecules and ions.
> - Water is important in human temperature regulation.

Water is the biological solvent

- A solvent is a liquid in which other substances dissolve, and a solute is any dissolved substance.
- Water keeps the ions dissolved
- Hydrophilic molecules are polar molecules that are attracted to water and interact with it easily
- Hydrophobic molecules are nonpolar, neutral molecules. They do not interact easily with water and generally won't dissolve in it.
- Water is a liquid at body temperature, it can flow freely. This makes it an excellent medium for transporting solutes from one place to another.

Water helps regulate body temperature

- An important property of water is that it can absorb and hold a large amount of heat energy with only a modest increase in temperature.
- The ability of water to absorb and hold heat helps prevent rapid changes in body temperature when changes occur in metabolism or the environment.
- One way to lose heat quickly is by evaporation of water. (evaporation of sweat is just one of the mechanisms for the removal of heat from the body)

> *Recap: Most biological molecules dissolve readily in water because water is a polar molecule. The liquid nature of water facilitates the transport of biological molecules. Water absorbs and holds heat and can lower body temperature through evaporation.*

4. The importance of hydrogen ions

- One of the most important ions in the body is the hydrogen ion, a single proton without an electron

> - Molecules that can donate a hydrogen ion (H+) are called acids. Molecules that can accept H+ are called bases.
> - The hydrogen ion concentration of a solution is expressed as PH.
> - Buffers are pairs of molecules that tend to minimize changes in PH when an acid or base is added to a solution.

Acids donate hydrogen ions, bases accept them

- Although the covalent bonds between hydrogen and oxygen in water are strong and thus rarely broken, it can happen. When it does
  - The electron from one hydrogen atom is transferred to oxygen atom completely and the water molecule breaks into two ions.
    - A hydrogen ion H+
    - A hydroxide ion OH –
- An acid is any molecule that can donate an H+ ion. When added to pure water, acids produce an acidic solution, one with an higher H+ concentration than that of pure water.
- A base is any molecule that can accept an H+ ion. When added to pure water, bases produce a basic of alkaline solution, one with a lower H+ concentration than that of pure water.

The pH scale expresses hydrogen ion concentration

- The ph scale is a measure of the hydrogen ion concentration of a solution
- Neutral water has a pH of 7.0
- An acidic solution has a pH of less than 7
- A basic solution has a pH of greater than 7
- Important to keep a low concentration of hydrogen ions in the body!
  ➔ They tend to displace other positive ions, altering shape and structure of molecules

> *Recap: Acids can donate hydrogen ions to a solution, whereas bases can accept hydrogen ions from a solution. The PH scale indicates the hydrogen ion concentration of a solution. The normal PH of blood is 7.4.*

Buffers minimize changes in pH

- A buffer is any substance that tends to minimize the changes in pH that might otherwise occur when an acid or base is added to a solution. Buffers are essential to our ability to maintain homeostasis of pH in body fluids.
- Most important buffer pair = bicarbonate and carbonic acid

> *Recap: Buffers tend to minimize changes in PH in a solution. They help us maintain a stable PH in body fluids.*

5. The organic molecules of living organisms

- Organic molecules are molecules that contain carbon and other elements held together by covalent bonds.

Carbon is the common building block of organic molecules

- Organic molecules = contain carbon and other elements held together by covalent bonds
- Carbon (koolstof) = common building block of all organic molecules
    - More stable when its second shell is filled with eight electrons
    - Natural tendency to form 4 covalent bonds with other molecules
    - Almost no limit to the size of organic molecules derived from carbon
- Macromolecules = consist of thousands or millions of smaller molecules

> - The backbone of all organic molecules as carbon.
> - Organic molecules are formed by a process called dehydration synthesis (requiring energy) and broken down by a process called hydrolysis (releasing energy).

Macromolecules are synthesized and broken down within the cell

- Dehydration synthesis = subunits are joined by covalent bonds
    - each time a subunit is added, the equivalent of a water molecule is removed (dehydration)
    - requires energy
- Hydrolysis = breakdown of organic macromolecules
    - Equivalent of a water molecule is added, each time a covalent bond between subunits is broken
    - Releases energy
- Living organisms synthesize 4 classes of organic molecules:

  1) carbohydrates
  2) lipids
  3) proteins
  4) nucleic acids

> *Recap: Carbon is a key element of organic molecules because of the multiple ways it van form strong covalent bonds with other molecules. Organic molecules are synthesized by dehydration synthesis, a process that requires energy, and broken down by hydrolysis, which liberates energy. The four classes of organic molecules are carbohydrates, lipids, proteins and nucleic acids.*

6. Carbohydrates: used for energy and structural support

- Carbohydrates = carbon + 2 hydrogen + oxygen
- Used for energy and structural support

> - Monosaccharides, or simple sugars, are a source of quick energy for cells.
> - Complex carbohydrates (polysaccharides) are formed by linking simple sugars (monosaccharides) together by dehydration synthesis.
> - Carbohydrates are primarily energy-storage molecules. Plants use them for structural support as well.
> - In animals the storage molecule is glycogen; in plants it is starch.

Monosaccharides are simple sugars

- Monosaccharide = carbon + 2 hydrogen + oxygen
    - Glucose, fructose, ribose and desoxyribose
    - Glucose = energy for cells

Oligosaccharides: more than one monosaccharide linked together

- Oligosaccharides = short strings of monosaccharides linked together by dehydration synthesis
    - Bvb: table sugar
    - Disaccharide = 2 monosaccharide

Polysaccharides store energy

- Polysaccharides = thousands of monosaccharides are joined together
    - Way for cells to store energy
        - Animals: glycogen / Plants: starch
    - Cellulose = structural support (plants)

> *Recap: Carbohydrates contain carbon, hydrogen and oxygen in a 1-2-1 ratio. Simple sugars such as glucose provide immediate energy for cells. Complex carbohydrates called polysaccharides store energy (in animals and plants) and provide structural support (in plants).*

7. Lipids: insoluble in water

- Lipids do not solve in water

> - Lipids include fats and oils, phospholipids and steroids. Lipids are insoluble in water.
> - Fats store energy. Phospholipids and cholesterol are important structural components of the cell membrane. The sex hormones are steroids synthesized from cholesterol.

Triglycerides are energy-storage molecules

- Triglycerides = (neutral) fats
  - Glycerol + 3 fatty acids (chains of hydrocarbons that end in a carboxyl group (COOH)
  - Saturated fats
    - solid at room temperature
    - Animal fats (butter, bacon grease)
    - Contributes to development of cardiovascular disease
  - Unsaturated fats = oils
    - Liquid at room temperature
  - Stored in adipose tissue
  - Important source of stored energy

> *Recap: lipids (triglycerides, phospholipids and steroids) are all relatively insoluble in water. Triglycerides are an important source of stored energy.*

Phospholipids are the primary component of cell membranes

- Primary structural component of cell membranes
- Glycerol + 2 fatty acids + phosphate group (PO4-) + …
- One end of molecule is polar (soluble in water), one end is neutral (insoluble in water)

Steroids are composed of four rings

- Relatively insoluble in water
- Bvb: cholesterol
  - Essential structural component of animal cell membranes
  - Source of several important hormones (o.a. estrogen, testosteron)

> *Recap: Phospholipids, an important component of cell membranes, have a polar (water-soluble) head and two fatty acid (water-insoluble) tails. Steroids, such as cholesterol, have a four ring structure.*

8. Proteins: complex structures constructed of amino acids

- Long strings of amino acids
- Differences in charge/structure of amino acids ➔ differences in shape/functions of proteins
- Formed by dehydration synthesis
- 3 to 100 amino acids = polypeptide
- 100+ amino acids = protein

Protein function depends on structure

- Primary structure: amino acid sequence
- Secondary structure: how the chain is orientated in space
    - Alpha helix
    - Beta sheet
    - Random coil
- Tertiary structure: how the protein twists and folds to form a 3-dimensional shape
- Quaternary structure: how many polypeptide chains make up the protein and how they associate with each other

- Functions
    - Structural support
    - Muscle contraction
    - Part of cell membrane
    - Enzymes

- Denaturation = permanent disruption of protein structure, leading to loss of function
    - Caused by high temperature or changes in pH

> - Proteins have unique three-dimensional structures that depend on their primary structure (their amino acid sequences). Living organisms construct a tremendous number of different proteins using just 20 different amino acids.
> - The human body contains thousands of proteins, each with a different function.
> - Enzymes are proteins that facilitate the rates of chemical reactions.

> *Recap: Proteins are complex molecules consisting of strings of amino acids. The function of a protein relates to its shape, which is determined by its amino acid sequence and the twisting and folding of its chain of amino acids. A denatured protein loses its shape and function.*

Enzymes facilitate biochemical reactions

- Enzyme = biological catalyst
  - Speeds up the rate of chemical reaction without itself being altered or consumed by the reaction
  - Break molecules apart or join them together
  - Reactants (= substrates) ➔ products
- Protein shape is in part determined by chemical/physical environment inside the cell
  - Temperature, pH, ion concentration
    ➔ importance of homeostasis!

Recap: Enzymes are proteins that facilitate biochemical reactions in the body. Without enzymes, many biochemical reactions would occur too slowly to sustain life.

9. Nucleic acids store genetic information

- DNA (deoxyribonucleic acid)
  - Genetic material of the cell
  - Directs and controls all of life's processes
- RNA (ribonucleic acid)
  - Responsible for carrying out instructions of DNA
- Importance:
  - DNA contains the instructions for producing RNA
  - RNA contains the instructions for producing proteins
  - Proteins direct most of life's processes
- Both DNA and RNA are composed of nucleotides (nucleotide consists of a five-carbon sugar, a single or double ringed structure containing nitrogen called a base, one or more phosphate groups)
  - 8 different nucleotides (4 in RNA + 4 in DNA)
  - DNA:
    - deoxyribose + phosphate group(s) + base
    - base = adenine, thymine, cytosine or guanine
    - 2 complementary strands (A with T, C with G)
  - RNA:
    - ribose + phosphate group(s) + base
    - base = adenine, uracil, cytosine or guanine
    - single-stranded molecule (complimentary copy of only one strand of DNA)
    - RNA is shorter (only the segment of DNA that codes for proteins)

- DNA is composed of two long strands of nucleotides intertwined into a double helix. DNA is constructed from just four different DNA nucleotides.
- RNA is a shorter single strand of RNA nucleotides, representing the code for one or more proteins

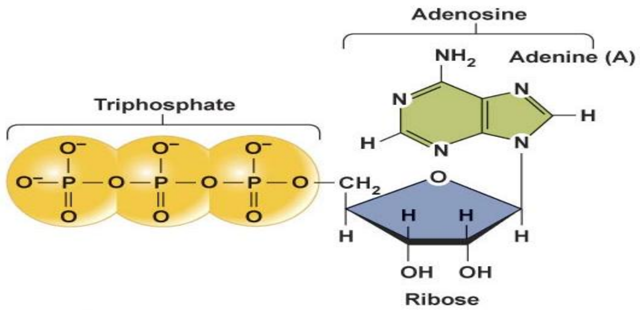
Recap: DNA and RNA are constructed of long strings of nucleotides. Double stranded DNA represents the genetic code for life, and RNA is responsible for carrying out those instructions.

10. ATP carries energy

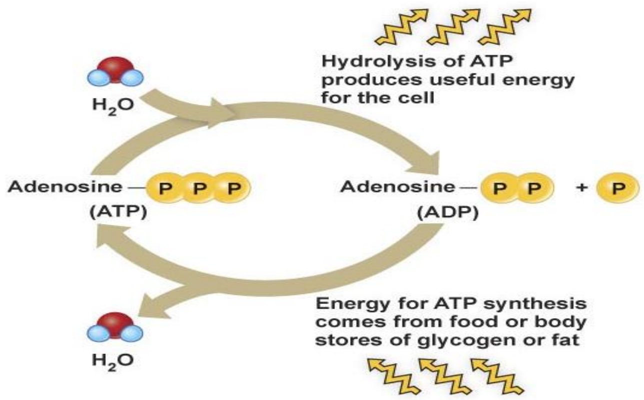
- ATP = adenosine triphosphate
- Adenine base + ribose + triphosphate
- bonds between phosphate groups cointain potential energy ➔ energy source for cells
- Cells can break down ATP for energy:
    - ATP → ADP (adenosine diphosphate) + Pi (inorganic phosphate group) + energy
    - Reaction is reversible!

- The nucleotide ATP is an energy source for cells. The energy is stored in the bonds between phosphate groups.

ATP is a nearly universal source of quick energy for cells. The energy is stored in the chemical bonds between phosphate groups.



a) ATP



b) The breakdown and synthesis of ATP

Structure and function of cells

- Cell doctrine:
    1) All living things are composed of cells and cell products
    2) A single cell is the smallest unit that exhibits all the characteristics of life
    3) All cells come only from preexisting cells

- All cells have a plasma membrane that surrounds and encloses the cytoplasm
- Eukaryotic cells have a nucleus

1. Cells are classified according to their internal organization

- All cells have a plasma membrane
    - Encloses the material inside the cell

Eukaryotes have a nucleus, cytoplasm and organelles

- Eukaryotes
    - Plasma membrane
    - Nucleus = centre of information, houses genetic material
    - Cytoplasm: cytosol + organelles

Prokaryotes lack a nucleus and organelles

- Prokaryotes
    - Vb: Bacteria
    - Plasma membrane surrounded by a rigid cell wand
    - Genetic material isn't enclosed in a nucleus
    - Lack most of the organelles found in eukaryotes

2. Cell structure reflects cell function

- Strong link between structure and function

- Limits of cell size are imposed by the mathematical relationship between cell volume and cell surface area.
- Various types of microscopes with magnifications up to 100 000-fold enable us to visualize cells and their structures.

Recap: Common features of nearly all eukaryotic cells are plasma membrane, a nucleus, organelles and the cytoplasm. Differences in cell shape and internal organization reflect differences in function.

Cells remain small to stay efficient

- All cells are small, because:
  - The total metabolic activities of a cell are proportional to its volume of cytoplasm, which is in effect its size
  - All raw materials, energy, and waste can enter or leave the cell only by crossing the plasma membrane
  - As objects get larger, their volume increases more than their surface area
    ➔ The smaller a cell is, the more effectively it can obtain raw materials and get rid of wastes
- Microvilli = effective way to increase surface area relative to volume

Recap: cells exchange materials with their environment across their plasma membrane. Cells divide to remain small, because the makes them more efficient at obtaining nutrients and expelling wastes.

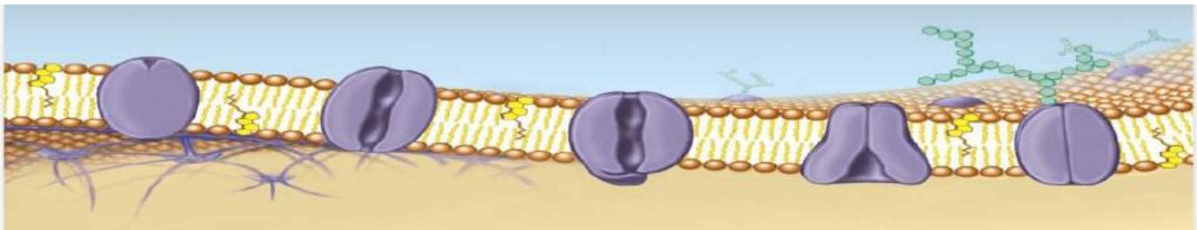
3. A plasma membrane surrounds the cell

- The plasma membrane is a bilayer of phospholipids that also contains cholesterols and various proteins.

The plasma membrane is a lipid bilayer

- Constructed of:
  - Lipid bilayer
    - polar head (water-soluble) and nonpolar tails (water-insoluble)
    - Polar heads face outward, nonpolar tails face inward
  - Cholesterol
    - Make the plasma membrane more rigid
  - Proteins
    - Transporting molecules and information across the plasma membrane
- Plasma membranes of animal cells are not rigid (flexible)
- Phospholipids and proteins are not anchored to specific positions in the plasma membrane

Recap: the plasma membrane allows some substances to move into and out of the cell but restricts others. Its phospholipid bilayer contains cholesterol for rigidity and proteins for information transfer, transport of molecules and structural support.



4. Molecules cross the plasma membrane in several ways

- Some molecules are transported across the plasma membrane passively (by diffusion), whereas others are transported by active processes requiring the expenditure of energy.
- Receptor proteins transfer information across the plasma membrane.
- The sodium-potassium pump is a plasma membrane protein with a critical role in the maintenance of cell volume

Passive transport: principles of diffusion and osmosis

Passive transport

- Doesn't require energy

Recap: Molecules diffuse from a region of higher concentration to a region of lower concentration. The net diffusion of water across a selectively permeable membrane is called osmosis.

Diffusion:

- Molecules in a gas/liquid move about randomly, colliding with other molecules and changing direction
- Diffusion = movement of molecules from one region to another as a result of this random motion
- Molecules will tend to diffuse away from area of high concentration and toward region of low concentration
- Requires a concentration gradient between 2 points
- Once the concentration of molecules is the same throughout the solution, a state of equilibrium exists in which molecules diffuse randomly but equally in all directions
- Pure water = solution with the highest possible concentration of water

Osmosis

- Plasma membrane is selectively permeable
  - Highly permeable of water, but not to all ions or molecules
  - Net diffusion of water across a selectively permeable membrane = osmosis
  - Fluid pressure to exactly oppose osmosis = osmotic pressure

Passive transport moves with the concentration gradient

Recap: Diffusion and facilitated transport are both forms of passive transport. They do not require the expenditure of energy.

Diffusion through the lipid bilayer

- Allows passage of some molecules while restricting others
- 2 important lipid-soluble molecules: O2 and CO2

Diffusion through channels

- Constructed of proteins that span the entire lipid bilayer
- Some channels are open all the time, others are gated
- Important in regulating transport of ions (sodium, potassium and calcium) in cells that are electrically excitable

Facilitated transport

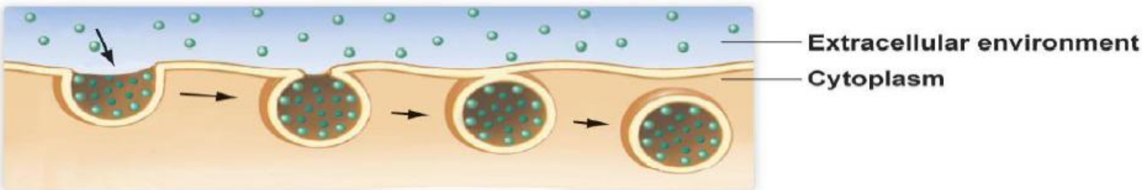
- = facilitated diffusion
- Molecule attaches to a membrane protein, triggering a change in the protein's shape or orientation that transfers the molecule to the other side of the membrane
- = transport protein or carrier protein

Active transport requires energy

- Can move substances through the plasma membrane against their concentration gradient
- Requires energy (ATP → ADP + Pi + energy)
- Pumps = proteins that actively transport molecules across the plasma membrane
- Bvb: sodium-potassium pump
- Not all active transport pumps require ATP: some pumps derive energy from "downhill" facilitated transport and use it to transport another molecule "uphill"

Endocytosis and exocytosis move materials in bulk

- Some molecules are too big to be transported by the previous methods
- Endocytosis: moves material into the cell

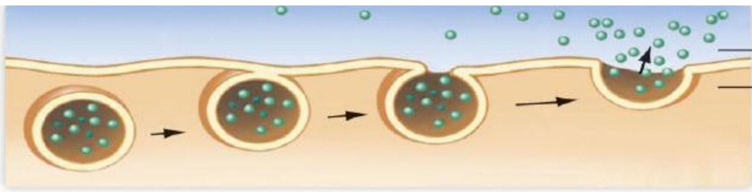


a) Endocytosis

Endocytose

- Materialen in de cel transporteren
- Exterieure moleculen lossen op in het celmembraan
- De moleculen met het celmembraan vormen een blaasje en zet zich af tegen het celmembraan
- Sommige blaasjes hebben receptoren op hun oppervlakte die alleen binden aan specifieke moleculen (bv: insuline en verschillende enzymen)
- Geen receptoren (water,nutriënten) vooral bij verteringsmoleculen

- Exocytosis: moves material out of the cell



b) Exocytosis

Exocytose

- Materialen uit de cel transporteren
- Blaasjes in de cel smelt samen met celmembraan
- Inhoud blaasje wordt losgelaten in het exterieur
- Bv : giftige afvalstoffen,onverteerbaar materiaal,speciale producten

Information can be transferred across the plasma membrane

- Receptor proteins: span the plasma membrane and can receive and transmit information across the membrane
    - Binding of a molecule to a receptor site (lock-and-key system) triggers biochemical reactions that ultimately cause changes within the cell
    - Highly specific for a particular molecule

The sodium-potassium pump helps maintain cell volume

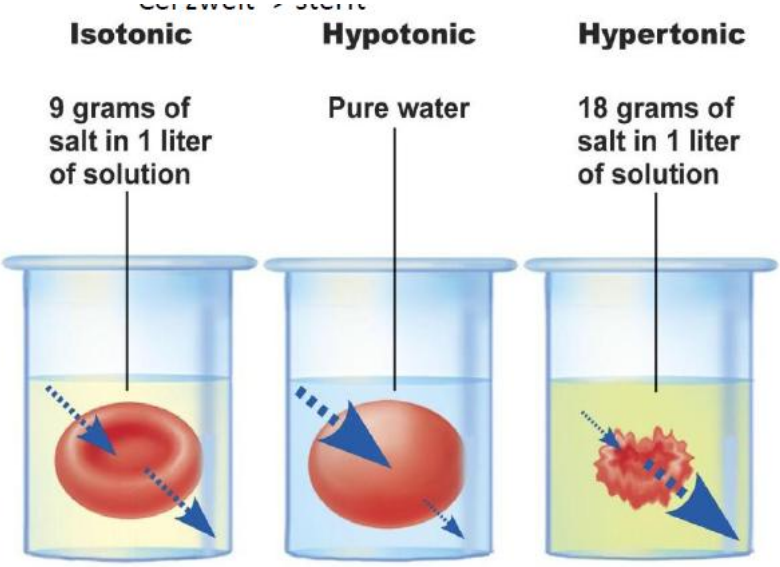
- Cells tend to accumulate certain materials depending on what is available in their extracellular environment
- Water diffuses from outside the cell toward the high cytoplasmic solute concentration
    - Would increase cell volume, eventually causing the cell to rupture
- The cell gets rid of ions it doesn't need in large quantities in exchange for those it must stockpile
    - Keeps the solute concentration in cytoplasm identical to the solute concentration of extracellular fluid ➔ no net driving force for diffusion of water

= primary function of sodium-potassium pump

- 3 binding sites for sodium (inside the cell)
- Binding of sodium triggers breakdown of ATP to release energy
- ATP causes pump to change shape, expelling sodium ions and exposing 2 binding sites for potassium (outside the cell)
- Binding of potassium triggers another change of shape, transporting potassium into the cell

Isotonic extracellular fluid also maintains cell volume

- Tonicity = relative concentration of solutes in two fluids
  - Ability of a human cell to control its volume also depends on the tonicity of the extracellular fluid
  - Isotonic extracellular fluid has the same concentration as the intracellular fluid
  - Hypertonic solution: higher concentration of solutes than intracellular fluid
    - Water diffuses out of the cells, cells shrink (and die)
  - Hypotonic solution: lower concentration of solutes than intracellular fluid



- Water diffuses into the cells, cells swell (and die)

Recap: The Sodium-potassium pump is an essential mechanism in the regulation of cell volume. In addition, homeostatic regulatory processes keep the tonicity of the extracellular fluid relatively constant.

5. Internal structures carry out specific functions

- The nucleus directs all of the cell's activities
- Ribosomes, the endoplasmic reticulum and the Golgi Apparatus participate in the synthesis of life's molecules
- Vesicles are membrane-bound spheres that transport, store and ship cellular products and toxic or dangerous materials.
- Mitochondria make energy available for the cell in the form of high-energy molecule ATP.

The nucleus controls the cell

- Nucleus
  - Information center of the cell
  - Contains most of the cell's genetic material (DNA)
    - DNA controls nearly all activities of the cell
- Nuclear membrane with nuclear pores
- Nucleolus: synthesizes RNA and proteins that compose ribosomes

Ribosomes are responsible for protein synthesis

- Ribosomes
  - Composed of RNA and certain proteins
  - Either freely floating in cytosol or attached to the endoplasmatic reticulum
  - Responsible for making specific proteins

The endoplasmatic reticulum is the manufacturing center

- Endoplasmatic reticulum (ER)
  - Synthesizes most of the chemical compounds made by the cell
  - With ribosomes: rough ER
    - Synthesis of proteins
    - Move from rough ER to smooth ER
  - Without ribosomes: smooth ER
    - Synthesis of macromolecules other than protein
      - Mostly lipids (some hormones)
    - Packaging of proteins and lipids for delivery to the Golgi apparatus

Recap: The nucleus contains most of the cell's genetic material. Ribosomes composed of RNA and ribosomal proteins assembly. The endoplasmic reticulum modifies some of the proteins, manufactures most other macromolecules in rough form, and transfers them to Golgi apparatus.

The golgi apparatus refines, packages and ships

- Golgi apparatus
  - Cell's refining, packaging, and shipping center
  - Contains enzymes that further refine the products of the ER into final form

Vesicles: Membrane-bound storage and shipping containers

- Vesicles
  - Membrane-bound spheres that enclose something within the cell
  - Vesicles that ship and store cellular products
    - Enclose and transport products of ER and Golgi apparatus
    - Remains in cytoplasm if the products are not immediately needed
  - Secretory vesicles
    - Contain products destined for export from the cell
    - Release their contents by exocytosis
  - Endocytotic vesicles
    - Enclose bacteria and raw materials from the extracellular environment
    - Bring them into the cell by endocytosis
  - Peroxisomes and lysosomes
    - Contain enzymes so powerful that they must be kept within the vesicle to avoid damaging the rest of the cell
    - Peroxisomes:
      - destroy various toxic wastes produced in the cell
      - destroy compounds that have entered the cell from outside
      - process occurs entirely within the peroxisome
    - Lysosomes:
      - Contain powerful digestive enzymes
      - Fuse with endocytotic vesicles to digest bacteria etc.
      - Dissolve and remove damaged mitochondria
      - When their digestive task is complete, they become residual bodies (can be stored in the cell or eliminated by exocytosis)

Recap: The Golgi apparatus refines cellular products to their final form and packages them in membrane-bound vesicles. Some vesicles store, ship and secrete cellular products; others digest and remove toxic waste and cellular debris.

Mitochondria provide energy

- Mitochondria
  - Provide the cell of energy
  - Smooth outer membrane covers the entire surface
  - Inner membrane with numerous folds that increase the surface area
  - Contain hundreds of protein enzymes to break down food and release energy
  - Energy is used to create ATP, which is then released in the cytosol

Fat and glycogen: sources of energy

- Some cells store raw energy as lipids (fat) or glycogen granules
  - Energy stored in glycogen can be used to produce ATP more quickly than energy derived from fat

Recap: Mitochondria manufacture ATP for the cell. Some cells stockpile fats or glycogen, which they can use to make more ATP as needed.

6. Cells have structures for support and movement

- A cytoskeleton of microtubules and microfilaments serves as structural support and anchors the various organelles.
- Cilia and flagella provide for movement in certain types of cells. Both cilia and flagella are made of pairs of protein microtubules.

The cytoskeleton supports the cell

- Cytoskeleton
  - loosely structured network of fibers (microtubules and microfilaments)
  - Framework for the soft plasma membrane
  - Supports and anchors other structures within the cell

Cilia and flagella are specialized for movement

- Cilia
  - Hairlike, extend from the surface
  - Cilia move materials along the surface of a cell with a brushing motion
  - 9 pairs of fused microtubules surround 2 single microtubules in the center
- Flagella
  - found only on sperm cells
  - whiplike movement moves the entire sperm cell from one place to another
  - similar structure as cilia

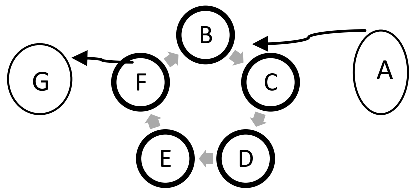
Centrioles are involved in cell division

- Centrioles
  - Short rodlike microtubular structures located near the nucleus
  - Essential for cell division (see Chapter 17)

Recap: The cytoskeleton forms a supportive framework for the cell. Cilia and flagella are specialized for movement, and centrioles are essential to cell division.

7. Cells ure and transform matter and energy

- Metabolism : the sum of all the chemical reactions in the organism
- Metabolic pathways: chemical reactions that are organized, in wich one reaction follow after another in orderly and predictable patterns.
  - Metabolic pathways LINEAIR: the product from one chemical reaction becomes the substrate for the next
    A → B → C→ D
  - Metabolic pathways CYCLE: substrate molecules enter and product molecules exit.



- There are 2 basic types of metabolic pathways:
  - Anabolism: molecules are assembled into lager molecules that contain more energy, a process that requires energy. (vb; assembly of a protein)
  - Catabolism: larger molecules are broken down, a process that releases energy.

- Two important facts about metabolic pathways.
  - Every chemical reaction requires a specific enzyme.
  - The metabolic activities of living cells require a lot of energy.
    ➔ Cells get their energy by catabolism of molecules that serve as chemical stores of energy

> - The creation and destruction of molecules either requires energy or liberates energy
> - The most rapidly useful form of energy for cells is ATP.
> - The production of ATP from glucose requires four consecutive stages: glycolysis, a preparatory step, the critic acid cycle and the electron transport system
> - Cells can utilize glycogen, fats or proteins fer energy.
> - Only a small amount of ATP can be made in the absence of oxygen.

> *Recap: Metabolism refers to all of cell's chemical processes. Metabolic pathways either create molecules and use energy (anabolism) or break them down and liberate energie (catabolism)*

Glucose provides the cell with energy

- Glucose = most readily available source of energy
  - Derived from food or stored glycogen
  - Production of ATP:
    1) glycolysis: glucose ➔ 2 three-carbon pyruvate molecules
    2) preparatory step: pyruvate enters mitochondrion ➔ acetyl CoA + energy
    3) citric acid cycle: acetyl CoA ➔ energy
    4) electron transport system: energy is used to produce ATP from ADP
- Most of the body's energy reserves do not take the form of glycogen
  - Our body may utilize fats and proteins (fig. 3.30, HB p. 74)
- A small amount of ATP can be made in humans by anaerobic metabolism (without oxygen) for at least brief periods of time
  - Bvb: glycolysis
  - Glucose ➔ pyruvate ➔ lactic acid
  - Lactic acid causes burning sensation and cramps associated with muscle fatigue when not enough oxygen is available to muscle tissue
  - When oxygen becomes available again, the lactic acid is metabolized by aerobic pathways
- Glucose is the only fuel that can be used under anaerobic conditions

Fats and proteins are additional energy sources

- Energy is constantly being transferred into and out of the body.
- When we eat more calories than we can use immediately some of the excess energy goes to replenish the body's stores of glycogen and the rest is converted to fat and stored in fat tissue.

Anaerobic pathways make energy available without oxygen

- Cellular respiration requires oxygen to complete the chemical reactions of the citric acid cycle and the electron transport chain.
- A small amount of ATP can be made in humans by anaerobic metabolism(

Recap: carbohydrates and fats are the main sources of stored energy for making ATP, although proteins can be used if necessary. In the absence of oxygen, only glucose can be used, and only very limited amounts of ATP are produced.

without oxygen) for at least brief periods of time.

From cells to organ systems

1. Tissues are groups of cells with a common function

- A multicellular organism consists of many cells that collectively share the functions of life. All cells in a multicellular organism have a specialized function that benefits the organism in some way.
- Tissues: are groups of specialized cells that are similar in structure and that perform common functions.

> - The four types of tissues are epithelial tissue, connective tissue, muscle tissue, and neural tissue

2. Epithelial tissues cover body surfaces and cavities

- Epithelial tissues consist of sheets of cells that line or cover various surfaces and body cavities.
  - Epithelial tissues protect the underlying tissues.
  - They are smooth to reduce friction
  - Help blood flow more easily trough your body
  - Absorb water and nutrients across your intestines into your blood.
- Glands are epithelial tissues that are specialized to synthesize and secrete a product.
  - Exocrine glands: secrete their products into a hollow organ or duct
  - Endocrine glands: secrete substances called hormones into the bloodstream.

> - Epithelial tissues are sheets of cells that cover of line body surfaces and form the glands.
> - Epithelial tissues are supported by a noncellular layer called the basement membrane.

Epithelial tissues are classified according to cell shape

- Squamous epithelium :
  - consists of one of more layers of flattened cells.
  - Forms the outer surface of the skin
  - Lines the inner surfaces of the blood vessels, lungs, mouth and troat, and vagina.
- Cuboidal epithelium:
  - Composed of cube-shaped cells.
  - Forms the kidney tubules and also covers the surfaces of the ovaries.

- Columnar epithelium:
    - Composed of tall rectangular cells.
    - Lines parts of the digestive tract, certain reproductive organs and the larynx.
    - Certain cells within the columnar epithelium are called *Goblet Cells.* → secret mucus, a thick fluid that lubricates the tissues and traps bacteria, viruses and irritating particles.

- Not only classified by shape but also by the number of cell layers.
  → A simple epithelium is a single layer of cells. Simple E is so thin that molecules can pass through it easily.
  → a stratified epithelium consists of multiple layers (or strata). Stratified E is thicker and provides protection for underlying cells.

The basement membrane provides structural support

- Basement membrane: is a supporting non-cellular layer. Directly beneath the cells of the epithelial tissue.
- In addition to being attached to a basement membrane, epithelial cells may be connected to each other by several types of cell junctions.
    - Tight junctions:
        - seal the plasma membranes of adjacent cells → so nothing can pass between the cells.
        - Important in epithelial layers that must control the movement of substances into or out of the body.
    - Adhesion junctions:
        - Allow for some movement between cells so that the tissues can stretch and bend
        - Found in the epithelium of your skin -> allow you to move freely
    - Gap junctions:
        - Represent the conntecting channels made of proteins that permit the movement of ions or water between two adjacent cells.
        - They are commonly found in the epithelial cells in the liver, heart, and some muscle tissue.

Recap: Epithelial tissues line body surfaces and cavities, and form glands. They are classified according to cell shape (squamous, cuboidal, or columnar) and the number of cell layers (simple of stratified).

3. Connective tissue supports and connects body parts

- Connective tissue:
  - supports the softer organs of the body against gravity and connects the parts of the body together.
  - it also stores fat and produces the cells of blood.
  - Most connective tissues have few living cells
    - Their structure consists of nonliving extracellular material, the matrix
    - That is synthesized by connective tissue cells and released into the space between them

- Fibrous connective tissues contain several types of extracellular fibers and only a few living cells. They support and connect body parts.
- Cartilage, blood, bone , and adipose tissue are classified as special connective tissues.

<u>fibrous connective tissue</u>

Type	Structure	Attributes	locations
Loose	Mostly collagen and elastin fibers No particular pattern More ground substance	Flexible but only moderately strong	Surrounds internal organs, muscles, blood vessels
Dense	Mostly collagen In a parallel arrangement of fibers Less ground substance	Strong	In tendons, ligaments and the lower layers of skin
Elastic	High proportion of elastin fibers	Stretches and recoils easily	Surrounds hollow organs that change shape or size regularly
Reticular (lymphoid)	Mostly thin, interconnecting reticular fibers of collagen	Serves as a flexible internal framework	In soft organs such as liver, spleen, tonsils and lymph glands.

Special connective tissue

Type	Structure	Attributes	Locations
Cartilage	Primarily collagen fibers in a ground substance containing a lot of water	Maintains shape and resists compression	Embryonic tissue that becomes bone. Also the nose, vertebral disks and the lining of joint cavities
Bone	Primarily hard mineral deposits of calcium and phosphate	Very strong	Forms the skeleton
Blood	Blood cells, platelets, and blood fluid called plasma	Transports materials and assists in defense mechanisms	Within cardiovascular system
Adipose tissue	Primarily cells called adipocytes filled with fat deposits	Stores energy in the form of fat.	Under the skin, around some internal organs

Fibrous connective tissues provide strength and elasticity

- Fibrous connective tissue:
  - connect various body parts.
  - Provide strength, support and flexibility.
  - Consist of several types of fibers and cells embedded in a gel like ground substance.
    - Collagen fibers: made of protein, confer strength and slightly flexible.
    - Elastic fibers: made of primarily of the protein 'elastin', which can stretch without breaking.
    - Reticular fibers: thinner fibers of collagen that interconnect witch each other.
  - The various fibers are embedded in a ground substance.
    - Consisting of water, polysaccharides and proteins.
    - Contains several types of cells(among them fat cells, mast cells, various white blood cells) and fibroblasts (= are the cells responsible for producing and secreting the proteins that compose the collagen, elastic and reticular fibers.

Recap: Fibrous connective tissues hold body parts together. Fibrous connective tissues contain extracellular fibers of strong but flexible proteins, a few living cells, and a ground substance of polysaccharides, proteins, and water.

Specialized connective tissues serve special functions

- Specialized connective tissue: a diverse group that includes cartilage, bone, blood, and adipose tissue.
    - Cartilage
        - = the transition tissue from which bone develops.
        - Maintains the shape of certain body parts and protects and cushions joints.
        - Consist of collagen fibers.
    - Bone
        - = a specialized connective tissue that only contains a few living cells.
        - Matrix consists of hard mineral deposits (calcium/phosphate)
        - Bone contains numerous of blood vessels(unlike cartilage) → reason why it can heal within 4 to 6 weeks.
    - Blood
        - = consists of cells suspended in a fluid matrix called plasma.
        - Is considered a connective tissue because all blood cells derive from earlier cells located within the bone.
        - Red blood cells: transport oxygen and nutrients to body cells and carry away the waste products of the cells' metabolism.
        - White blood cells: function in the immune system that defends the body.
        - Platelets: participate in the mechanisms that cause blood to clot following an injury.
    - Adipose tissue
        - = highly specialized for fat storage,
            - located under the skin, serves as a layer of insulation.
            - Forms a protective layer around internal organs.
        - Has a few connective tissue fibers and almost no ground substance.

Recap: Among the specialized connective tissues, cartilage and bone provide support, blood transports materials throughout the body, and adipose tissue stores energy in the form of fat.

4. Muscle tissues contract to produce movement

- Muscle tissue
    - Consists of cells that are specialized to shorten(or contract), resulting in movement of some kind.
    - Is composed of tightly packed cells called muscle fibers.
        - Fibers are long and thin and aligned parallel to each other.
- Three types of muscle tissue : skeletal, cardiac and smooth.

Skeletal muscles move body parts

- Skeletal muscle tissue
  - Connects to tendons, which attach to bones. When skeletal muscles contract, they cause body parts to move.
  - Cells are arranged parallel
  - Skeletal muscle is called voluntary muscle because we can exert conscious control over its activity.

Cardiac muscles cells activate each other

- Cardiac muscle tissue
  - Is found only in the heart
  - The individual cells are much shorter than skeletal muscle fibers, and they only have one nucleus.
  - Cells are arranged parallel
  - Is called the involuntary muscle because the heart can contract rhythmically entirely on its own.

> - Muscle tissue is composed of either skeletal, cardiac, or smooth muscle cells.
> - Skeletal muscles are attached to bones by tendons.

Smooth muscle surrounds hollow structures

- Smooth muscle tissue
  - Surrounds hollow organs and tubes (incl blood vessels, digestive tract, uterus and bladder)
  - These slim cells are much smaller than skeletal muscle cells and have only one nucleus, like the cardiac muscle.
  - Is called involuntary muscle in that way that we cannot control its contractions consciously.

5. Nervous tissue transmits impulses

- Nervous tissue :
  - Consist primarily of cells that are specialized for generating and transmitting electrical impulses throughout the body.
  - Located in the brain, the spinal cord and the nerves that transmit information to and from various organs.

2 types of cells in the nervous tissue:

- Neurons: cells that generate and transmit electrical impulses.
  - Have three typical basis parts:
    - Cell body: where the nucleus is located
    - Dendrites: numerous cytoplasmic extensions that extend from the cell body and receive signals from other neurons
    - Axon: a long extension that transmits electrical impulses over long distances.
- Glial cells: plays a supporting role by surrounding and protecting neurons and supplying them with nutrients.

> - Neurons are specialized for conduction of electrical impulses.
> - Glial cells surround and protect neurons and supply them with nutrients.

> *Recap: The common feature of all muscle tissues (skeletal, cardiac, and smooth) is that they contract, producing movement. Nervous tissues serve as a communication network by generating and transmitting electrical impulses.*

6. Organs and organ systems perform complex functions

- Organs: are structures composed of two or more tissue types joined together that perform a specific function or functions.

> - The human body is composed of 11 organ systems, each of which has at least one broad function.
> - Membranes consisting of layers of epithelial and connective tissues line the body cavities.
> - Positions of body parts are described on three planes: midsagittal, frontal, and transverse.

The human body is organized by organ systems

- Organ systems: are groups of organs that together serve a broad function that is important to survival either of the individual organism or of the species.
- All of these organs must interact and be controlled and coordinated to accomplish their overall function.

> *Recap: An organ consists of several tissue types that join together to perform a specific function. An organ system is a group of organs that share a broad function important for survival.*

circulatory system

- transports materials to and from all cells
- praticipates in the maintance of body temperature
- praticipates in mechanisms of defense against disease and injury

lymphatic system

- returns excess tissue fluid to the circulatory system
- participates in both general and specific (immune) defense responses

urinary system

- maintains the volume and composition of body fluids
- excretes some waste products

reproductive system: male

- produces sperm
- participates in the delivery of sperm to the female

reproductive system : female

- produces eggs
- nutures the fertilized egg, developping embryo and fetus until birth.

respiratory system

- exchanges gases (oxygen and carbon dioxide) between air and blood
- praticipates in the production of sound (vovalization)

integumentary system

- protects us from injury, infection and dehydration
- participates in temperature control
- receives sensory input from the external environment

skeletal system

- protects, supports, and anchors body parts
- provides the structural framework for movement
- produces blood cells
- stores minerals

muscular system

- produces movement or resists movement
- generates heat

nervous system

- detects both external and internal stimuli
- controls and coordinates rapid responses to these stimuli
- integrates the activities of other organs systems

endrocrine system

- produces hormones that regulate many body functions
- participates with the nervous system in integrative functions

digestive system

- provides the body with water and nutriens
- (the liver) synthesizes certain proteins and lipids for the body
- (the liver) inactivates many chemicals, incl hormones, drugs and poisons

Tissue membranes line body cavities

- Tissue membranes : consisting of a layer of epithelial tissue and a layer of connective tissue line each body cavity and form our skin.
  - Serous membranes: line and lubricate body cavities to reduce friction between internal organs.
  - Mucous membranes: line the airways, digestive tract and reproductive passages. Globet cell within the epithelial surface secret mucus, which lubricates the membrane's surface and entraps foreign particles.
  - Synovial membranes: line the very thin cavities between bones in movable joints. These membranes secrete a watery fluid that lubricates the joint.
  - Cutaneous membrane: our skin.

Three different membranes:

- Plasma membrane: of phospholipids surrounding every cell
- Basement membrane: of extracellular material on which epithelial tissue rests
- Tissue membrane: consisting of several layers of tissue sandwiched together that cover or surround cavities, organs, en entire organ system

Describing body position or direction

Zie p 93 figure 4.9

> *Recap: The body's hollow cavities are lined by tissue membranes that support, protect, and lubricate cavity surfaces. Locations of cavities and body parts are described relative to three planes (midsagittal, frontal, and transverse), using pairs of directional terms such as "anterior" and "posterior".*

7. The skin as an organ system

- Integumentary system: the proper name for the skin and its accessory structures.

> - The skin functions as a protective barrier, participates in the maintenance of homeostasis, and provides us with sensory information about the external environment.
> - Skin has two layers: an outer epithelial layer called the epidermis and an inner connective tissue layer called the dermis
> - Skin also contains nerves, blood vessels, glands, hair follicles, and smooth muscle.

Skin has many functions

- Protection from dehydration
- Protection from injury
- Defense against invasion by bacteria and viruses
- Regulation of body temperature
- Synthesis of an inactive form of vitamin D
- Sensations: provides information about the external world via receptors for touch, vibration, pain and temperature.

Skin consists of epidermis and dermis

- Skin is a tissue membrane and that tissue membranes contain layers of epithelial and connective tissue
    - The outer layer: epidermis
    - The inner layer: dermis
    - Hypodermis: the skin rests on a supportive layer consisting of loose connective tissue containing fat cells.
- Epidermal cells are replaced constantly
    - Two types of cells make the epidermis: keratinocytes and melanocytes.
        - Kerationcytes: produces a tough, waterproof protein called keratin. Actively dividing keratinocytes located near the base of the epidermis are sometimes called basal cells.
        - Melanocytes: located near the base of the epidermis produce a dark-brown pigment called melanin.

- Fibers in dermis provide strength and elasticity
    - The dermis is primarily dense connective tissue consisting of collagen, elastic, and reticular fibers embedded in a ground substance of water, polysaccharides and proteins.
    - Papillae: The surface of the dermis has many small projections that contain sensory nerve ending and small blood vessels.
    - Other structures in the dermis
        - Hair
        - Smooth muscle
        - Sebaceous glands
        - Sweat glands
        - Blood vessels
        - Sensory nerve endings

Recap: The Skin is an organ because it consists of different tissues serving common functions. Functions of skin include protection, temperature regulation, vitamin D synthesis, and sensory reception.

8. Multicellular organisms must maintain homeostasis

- Internal environment of the organism: the environment that surrounds the cells of a multicellular organism.
- Interstitial fluid: the internal environment is a clear fluid
- Homeostasis: relative constancy of the conditions within the internal environment.

> - In a milticellular organism, the external environment of every cell is the internal environment of the organism
> - Relative constancy of the internal environment of the organism is called homeostasis.
> - Homeostasis is maintained by negative feedback control systems.
> - In a negative feedback control system, a change in the controlled variable sets in motion a sequence of events that tends to reverse (or negate) the initial change.
> - In the regulation of body temperature, sensors located throughout the body send information about temperature to the control center, located in the hypothalamus of the brain.
> - Possible responses to a change in body temperature include dilating or constricting the blood vessels to the skin, shivering (if temperature is too low), and sweating (if temperature is too high).

Homeostasis is maintained by negative feedback

- Negative feedback: control systems operate in such a way that deviations from the desired condition are automatically detected and counteracted.
- A negative feedback control system has the following components:
  - A controlled variable
  - A sensor
  - Control center
  - An effector
- The cycle is called a negative feedback because any change in the controlled variable triggers a series of events that ultimately opposes the initial change, returning the variable to its set point. → homeostasis is maintained

Negative feedback helps maintain core body temperature

- A prime ex. Of a negative feedback is the maintenance of homeostasis of your body temperature. Multiple organ systems participate in maintaining homeostasis.
- Hypothalamus: these sensors transmit signals via nerves to the control center, located in a region of your brain
- When your core temperature falls below its set point the hypothalamus:
  - Sends more nerve impulses to blood vessels in the skin, causing the blood vessels to constrict. This restricts blood flow to your skin and reduces heat loss.
  - Stimulates your skeletal muscles, causing brief bursts of muscular contraction known as shivering. Shivering generates heat.

- When your core temperature rises above its set point, the hypothalamus:
    - Sends fewer nerve impulses to blood vessels in the skin → blood vessels dilate. → increases blood flow to your skin and promotes heat loss.
    - Activates your sweat glands. As perspiration evaporates from your skin, you lose heat.
- Even when your core temperature is normal, your hypothalamus is transmitting some nerve impulses to the blood vessels in your skin.

Positive feedback amplifies events

- Positive feedback: control systems are relatively uncommon in living organisms. In positive feedback, a change in the controlled variable sets in motion a series of events that amplify the original chance, rather than returning it to normal.

Recap: All multicellular organisms must maintain homeostasis of their internal environment. In a negative feedback control system, any change in a controlled variable sets in motion a series of events that reverse the change, maintaining homeostasis.

the skeletal system

1. The skeletal system consists of connective tissue

- Bones are the hard elements of the skeleton.
- Ligaments consist of dense connective tissue, they bind the bones to each other.
- Cartilage is a specialized connective tissue primarily of fibers of collagen and elastic in a gel-like fluid called ground substance.

> - Connective tissues of the skeletal system are bones, ligaments, and cartilage.
> - Bone is a living tissue composed of cells and extracellular material.
> - Ligaments, composed of dense fibrous connective tissue, attach bones to each other.
> - Cartilage forms the intervertebral disks and lines the points of contact between bones.

Bones are the hard elements of the skeleton

- Bones consist of nonliving extracellular crystals of calcium minerals that give bones their hard, rigid appearance and feel.
- Important functions:
  - Support
  - Protection
  - Movement
  - Blood cell formation
  - Mineral storage

> *Recap: Bones contribute to support, movement, and protection. They also produce the blood cells and store minerals.*

Bone contains living cells

Fig. 5.1 p 105 +Txt

> *Recap: Bone may be compact or spongy in appearance. Long bones have a hollow shaft of compact bone filled with yellow marrow; spongy bone with red bone marrow is found in the epiphyses.*

Ligaments hold bones together

- Ligaments:
  - attach bone to bone.
  - consist of dense fibrous connective tissue, meaning that they are a regular array of closely packed collagen fibers all oriented in the same direction with a few fibroblasts in between.
  - Confer strength to certain joints while still permitting movement of the bones in relation to each other.

Cartilage lends support

- Cartilage
  - Contains fibers of collagen and/or elastin in a ground substance of water and other materials.
  - Smoother and more flexible than bone.
  - Three types :

- Fibro cartilage: consists primarily of collagen fibers arranged in thick bundles.
- Hyaline cartilage: smooth, almost glassy cartilage of thin collage, fibers
- Elastic cartilage: mostly elastin fibers, is highly flexible.

2. Bone development begins in the embryo

- After about two months of fetal development, rudimentary models of bones have been formed from cartilage.
- Throughout the rest of fetal development and on into childhood, bone-forming cells called osteoblasts replace the cartilage model with bone.
- Growth in the length of long bones centers on growth plates in each epiphysis

- Chondroblasts: cartilage-forming cells who form the rudimentary models of future bones are created out of hyaline cartilage.
- Ossification: The chondroblasts slowly die out and the cartilage models begin to dissolve and are replaced by bone.
- After the condoblasts die, the cartilage models break down inside and make room for the blood vessels to develop.
- Osteoblast: the blood vessels carry bone- forming cells.
  - They secrete ostoied(mix of proteins) which forms a matrix that provides internal structure and strength to the bone.
  - They also secrete (hydroxyapatite) enzymes that facilitate the crystallization of hard mineral salts of calcium phosphate around and between the matrix.
- Bones continue to lengthen throughout childhood and adolescence. This is because a narrow strip of cartilage called the growth plate. (or epihyseal plate)
- Bones also grow in width as osteoblasts lay down more bone on the outer surface just below the periosteum.
- The bone development process is controlled by hormones, secreted by the endocrine glands.

Recap: Bone-forming cells called osteoblasts produce a protein mixture (including collagen) that becomes bone's structural framework. They also secrete an enzyme that facilitates minerals deposition within the protein matrix.

3. Mature bone undergoes remodeling and repair

- Bone is a dynamic tissue that undergoes constant replacement, remodeling and repair.
- Osteoclast: a type of bone cell that is part due remodeling and repairing of the bone

Type of cell	function
Chondroblasts	Cartilage-forming cells that build a model of the future bone
Osteoblasts	Young bone-forming cells that

	cause the hard extracellular matrix of bone to develop
Osteocytes	Mature bone cells that maintain the structure of bone
Osteoclasts	Bone-dissolving cells

- Bone undergoes replacement throughout life.
- Bones can change shape over time, depending on the forces to which they are exposed.
- The process of bone repair includes: (1) the formation of a hematoma, (2) the formation of a fibro cartilage callus that binds the broken ends together, and (3) the eventual replacement of the callus with new bone.

Bone cells can change in shape, size and strength

- The maintance of homeostasis of bone structure depends on the precise balance of the activities of osteoclasts and osteoblasts.
- Osteoporosis: is a common condition in which bones lose a great deal of mass because of an imbalance over many years in the rates of activities of these two types of bone cells

Bone cells are regulated by hormones

- The rates of activities of osteoblasts and osteoclasts are regulated by hormones that function to maintain calcium homeostasis.
- When blood levels of calcium fall below a given point, parathyroid hormone stimulates the osteoclasts to secrete move bone dissolving enzymes.
- If calcium levels rise, than another hormone called calitonin stimulates osteoblast activity causing calcium and phosphate to be removed from blood en deposited in bone.

Bones undergo repair

- When you break a bone the blood vessels supplying the bone bleed into the area producing a mass of clotted blood called a hematoma.
- The repair process begins within days as fibroblasts migrate to the area. Some of the fibroblasts become chondroblasts, and together they produce a tough fibro cartilage bond, a callus between two broken ends of the bone.
- Then osteoclasts arrive and begin to remove dead fragments of the original bone and the blood cells of the hematoma.
- Finally, osteoblasts arrive to desposit osteoid matrix and encourage the crystallization of calcium phosphate minerals, converting the callus into bone.
- Eventually, the temporary union becomes dense and hard.

4. The skeleton protects, supports and permits movement

- The axial skeleton is represented by the skull, the vertebral column, the sternum, and the ribs.
- In the vertebral column, intervertebral disks of fibrocartilage absorb shock and permit limited movement
- The appendicular skeleton includes the pectoral gridle, the pelvic gridle, and the upper and lower limb

- Long bones: which include the bones of the imbs and fingers
- Short bones: (bones of the wrists) are approximately as wide as they are ling
- Flat bones: (including the cranial bones, the sternum, and the ribs)are thin, flattened and sometimes curved with only a small amount of spongy bone sandwiched between two layers of compact bone.
- Irregular bones: such as the coxal (hip) bones ans the vertebrae include a variety of shapes that don't fit into the other categories

- The skeleton: all the 206 bones of the human body and various connective tissue that hold them together.
- Three important functions:
  - It serves as a structural framework for support of the soft organs
  - It protects certain organs form physical injury
  - Because the way that the bony elements of the skeleton are joined together at joints, the presence of the skeleton permits flexible movement of most parts of the body.

The axial skeleton forms the midline of the body

- Axial skeleton consist of the skull, sternum, ribs and vertebral column.
  - The skull: cranial and facial bones
    - The skull comprises over two dozen bones that protect the brain and form the structure of the face
    - The cranial bones: are flat bones in the skull that enclose and protect the brain
    - Frontal bone: comprises the forehead and the upper ridges of the eye sockets
    - Two parietal bones: at the upper left and right side of the skull
    - Temporal bones: Forming the lower left and right sides
    - Sphenoid bone: forms the back of both eye sockets
    - Ethmoid bone: contributes to the eye sockets and also helps support the nose
    - Nasal bones: underlie only the upper bridge of the nose
    - Lacrimal bones: at the inner eye sockets
    - Mandible: or lower jaw contains the sockets that house the lower row of teeth.
    - Occipital bone: curving underneath to form the back and base of the skull
    - Foramen magnum: the large opening near the base of the occipital bone. This is where the vertebral column connects to the skull and the spinal cord enters the skull to communicate with the brain.
    - Facial bones: compose the front of the skull
    - Maxilla: on each side of the nose, which form part of the eye sockets and contain the sockets thath anchor the upper row of teeth.
    - Palatine bones: forms the hard palate
    - Vomer bone: is part of the nasal septum that divides the nose into left en right halves.
    - Zygomatic bone: form the cheek bones and the outer portion of the eye sockets.
    - Sinuses: several of the cranial and facial bones contain air spaces. → makes the skull lighter and give the human voice its characteristic tone and resonance.
      - Each sinus is lined with tissue that secretes mucus a thick sticky fluid that helps trap foreign particles in incoming air.

- The vertebral column: the body main axis
    - The vertebral column: supports the head, protects the spinal cord and serves as the site of attachment for the four limbs and various muscles.
    - Consists of 33 irregular bones called vertebrae that extends from the skull to the pelvis.
    - We classify the vertebral column into five anatomical regions
        - Cervical (neck)- 7 vertebrae
        - Thoracic (the chest or thorax) – 12 v.
        - Lumbar (the lower portion or 'small' of the back, which forms the lumbar curve of the spine) – 5 v.
        - Sacral (in the sacrum or upper pelvic region) – in the course of evolution, the 5 sacral vertebrae have become fused.
        - Coccygeal (the coccyx or tailbone) – 4 fused vertebrae. The coccyx is all that remains of the tails of our ancient ancestors. → example of a vestigial structure(= a structure that hasn't got any function anymore)

- Vertebrae share two points of contact = articulations.
- Intervertebrae disks: serve as shock absorbers, protecting the delicate vertebrae from the impact of walking/jumping/other movements.
- The ribs and sternum protecting the chest cavity
    - 12 pair of ribs
    - Sternum or breastbone, flat blade shaped bone.(composed of 3 bones that fused together during time)
    - Floating ribs: the bottom two pairs of ribs
    - Rib cage: ribs + sternum + vertebral colomn.

Recap: The skull protects the brain, the vertebral column protects the spinal cord and supports the appendicular skeleton, and the rib cage protects the organs of the chest cavity.

The appendicular skeleton: pectoral girdle, pelvic girdle, and limbs.

- **Appendicular skeleton: incl the arms, legs and their attachments to the trunk.**
  - Appendiculair skelet
    - Schoudergordel
      - Wat?
        - Halsbeen (sleutelbenen)
        - Schouderbladen
      - Functie
        - Flexibiliteit aan bovenste ledematen
      - Structuur
        - Aanhechting via spieren en pezen
        - Bovenarm
          - Opperarmbeen (humerus)
        - Onderarm
          - Spaakbeen (radius)
          - Ellepijp (ulna)
        - Vuist
          - 8 handwortelbeentjes
        - Handpalm
          - 5 middelhandsbeentjes
        - Vingers
          - 14 kootjes
          - Opponeerbare duimen
      - Flexibiliteit → instabiliteit
        - Bv. Carpal tunnel syndroom
          - Pijn, tintelingen, gevoelloosheid

- Bekkengordel
  - Wat?
    - Heiligbeen
    - Staartbeen
    - Linker- & rechterheupbeen
  - Functie
    - Steun aan bovenlichaam (zwaartekracht)
    - Aanhechtingsplaats voor benen
    - Bescherming organen
    - (zwangerschap & geboorte)
  - Structuur
    - Dijbeen
      - Langste & sterkste been
      - Knie → heup
    - Scheenbeen (tibia)
      - Knie → enkel
      - Voorste been
    - Kuitbeen (fibula)
      - Vastgehecht aan scheenbeen
      - Achterste been
      - Knie → enkel
    - Knieschijf (patella)
    - Enkel & voet
      - 7 voetwortelbeentjes
      - 5 middelvoetsbeentjes
      - 14 kootjes

Recap: The pectoral girdle and upper limbs are capable of a wide range of motions (dexterous movement). The pelvic girdle supports the body's weight and protects the pelvic organs. The lower limbs are strong but less dexterous than the upper limbs.

~~5. Joints form connections between bones~~

~~Joints vary from immovable to freely movable~~

~~Ligaments, tendons and muscles strengthen and stabilize joints~~

6. Diseases and disorders of the skeletal system

- Sprains are the result of stretched or torn ligaments. Bursitis and tendinitis are caused by injuries to the bursae and tendons.
- Arthritis is a general term for joint inflammation.
- Osteoarthritis is a condition in which the cartilage covering the ends of the bones wears out and joint friction increases
- Osteoporosis is a condition caused by progressive bone loss over time.

Sprains mean damage to ligaments

- A sprain is due to stretched or torn ligaments.
- Accompanied by internal bleeding with subsequent bruising, swelling and pain.
- Takes a long time to heal → ligaments have few cells an poor blood supply.
- Minor sprains: the ligaments are only stretched, usually mend themselves with time.

Bursitis and tendinitis are caused by inflammation

- Refer to inflammation of bursae or tendons following injury.
- Causes: incl. tearing injuries to tendons, physical damage caused by blows to the joint, and even some bacterial infections.
- They do not heal quickly → not well supplied with blood vessels.

Arthritis is inflammation of joints

- Joints are exposed to high compressive forces and are prone to excessive wear caused by friction.
- Most common type of arthritis is osteoarthritis
  - The cartilage covering the end of the bones wear out.
- Rheumatoid arthritis
  - Also involves joint inflammation but it is caused by the body's own immune system, which mistakenly attacks the joint tissues.

Osteoporosis is caused by excessive bone loss

- Caused by excessive bone loss over time, leading to brittle, easily broken bones.
- Symptoms: hunched posture, difficulty walking, increased likelihood of bone fractures, especially of the spine and hip.
- Can be prevented:
  - get enough calcium and vitamin D
  - exercise throughout your life.
- Several medications to treat it.

The muscular system

1. **Muscles produce movement or generate tension**
   <u>ENKEL DE VERMELDE AFBEELDINGEN + TEKST OM ZE TE BEGRIJPEN</u>

The fundamental activity of the muscle is tension
Skeletal muscles cause bones to move (6.2)
A muscle is composed of many muscle cells.(6.3 en 6.4)
The contractile unit is a sarcomere (6.5)
Muscles require energy to contract and to relex (tab 6.1)

Blood

- The circulatory system: consists of the heart, the blood vessels and the blood that circulates through them.
- The transport role of the circulatory system:
  - Plays a central role in supplying all cells with what they need and removing substances they no longer need. The circularly system ensures that blood flows throughout the entire body, bringing the necessary raw materials to the interstitial fluid surrounding every living cell and removing the waste.

1. The components and functions of blood

- Blood is specialized connective tissue. It consists of specialized cells and cell fragments suspended in a watery solution of molecules and ions.
- 3 crucial tasks
  - Transportation: blood transports all substances needed anywhere by the body. And blood also transports the waste products of cellular metabolism away from body tissues to the organs that eliminate them from the body.
  - Regulation: blood helps to regulate the body temperature
  - Defense: blood contains specialized defense cells that help protect against infections and illness, and it has the ability to prevent excessive blood loss through the clotting mechanism.
  - Together these functions are crucial for maintaining homeostasis. Blood is so effective at performing these functions that so far scientists'' efforts to develop an artificial blood substitute have not been very successful.
  - Composition of blood table 7.1
    - They fall into two major categories: the liquid component (plasma) and the cellular component or formed elements (red cells, white cells and platelets)

- Blood consists of formed elements and plasma. Blood has transports, regulatory, and protective functions.
- Plasma contains numerous plasma proteins involved in transport, regulation of water balance, and protection. It also contains ions, hormones, nutrients, wastes and, gases.
- Erythrocytes (RBCs) are highly specialized for the transport of oxygen, but they also transport some carbon dioxide.
- Hemoglobin is the primary protein in red blood cells and gives blood its oxygen-carrying capacity.
- The formed elements of blood all originate from stem cells in red bone marrow
- Leukocytes (WBCs) defend the body against disease and the effects of injury.
- RBCs and WBCs have short life spans and must continually be replaced. RBC production is stimulated when the body detects low oxygen levels in the blood.
- Platelets are cell products that participate in blood hemostasis.

Recap: About 8% of our body weight is blood. Blood maintains homeostasis by (1) transporting nutrients and exporting wastes, (2) regulating temperature and water volume, and (3) carrying molecules that fight disease and promote healing.

Plasma consists of water and dissolved solutes

- Plasma: is the transport medium for blood cells and platelets.
- Plasma proteins: which serve a variety of functions. Important plasma proteins incl. albumins, globulins and clotting proteins.
    - Albumins: which primarily serve to maintain the proper water balance between blood and the interstitial fluid.
    - Globulins: are a diverse group of proteins that transport various substances in the blood
        - When a protein attaches to one of the molecules, it creates a complex called a lipoprotein.
    - Clotting proteins: a third group of plasma proteins play an important role in the process of blood clotting.

Recap: about 55% of whole blood consists of plasma. Plasma is mostly water and serves as the medium in which all other blood components are dissolved and transported. Plasma proteins include albumins, globulins, and clotting factors.

Red blood cells transport oxygen and carbon dioxide

- Red blood cells (RBCs) are also called erythrocytes
  - Function: as carries of oxygen and carbon dioxide
  - The give blood its color and are the major reason why it is viscous.
  - Are small, flattened, doughnut shaped disks whose centers are thinner than their edges.
  - Red blood cells are highly specialized to transport oxygen.
- Hemoglobin: hemoglobin consists of four polypeptide chains, each containing a heme group.
  - Several factors influence the binding of hemoglobin to oxygen. Hemoglobin binds oxygen most efficiently when the concentration of oxygen is relatively high and the pH is fairly neutral.
  - Hemoglobin with 4 oxygen molecules attached called oxyhemoglobin. Has a red bright color.
  - Hemoglobin that has given up its oxygen is called desoxyhemoglobin. Color = dark purple. → because venous blood returning from the cells contains a mix of oxyhemoglobin and desoxyhemoglobin, venous blood generally has a dark red of maroon color that is between red & purple.

Recap: the ability of RBCs to transport nearly all of the oxygen and some of the carbon dioxide in blood depends on hemoglobin, the primary protein within red blood cells. Each molecule of hemoglobin contains four atoms of iron that can bind reversibly to oxygen.

Hematocrit and hemoglobin reflect oxygen-carrying capacity

- Hematocrit: the percentage of blood that consists of blood cells.
- An unusual hematocrit may be cause for concern. A low hematocrit may signal anemia or other disorders of inadequate red blood cell production
  - A high hematocrit can also be risky because excessive red blood cells thicken blood and increase the risk of blood clots.
  - In rare cases a high hematocrit could signal polycythemia → a disorder of the bone marrow characterized by an overproduction of red blood cells.

All blood cells and platelets originate from stem cells

- All blood cells and platelets originate from cells in the red marrow of certain bones: stem cells.
- Divide repeatedly throughout our lives, continually producing immature blood cells. These immature cells develop into platelets, and the various types of mature red and white blood cells → zie fig 7.5 p 148

RBCs have a short life span

- Some stem cells develop into immature cells called erythroblasts.
- Old and damaged RBC's are removed from the circulating blood and destroyed in the liver and spleen by large cells: macrophages.
  - Are derived from monocytes, the largest of white blood cells.
  - Surround, engulf and digest the red blood cell. This process this called phagocytosis.

- The heme groups are converted by the liver to a yellowish pigment called bilirubin.
- High circulating levels of bilirubin make skin and mucous membrands look yellowish and an the the whites of the eyes yellow. = jaundice.
  - Can also be caused by an increase in the rate of RBC breakdown.

RBC production is regulated by a hormone

- Regulation of RBC production is a negative feedback control loop that maintains homeostasis.
- If oxygen ava+ilability fails for any reason these cells cause the kidneys to secrete a hormone called erythropoietin. → E. is transported in the blood to the red bone marrow where it stimulates stem cells to produce more red blood cells.
- Blood doping: Some athletes have abused erythropoietin by injecting it to increase their RBC production and thus their blood oxygen-carrying capacity.

Recap: All blood cells and platelets are derived from stem cells in red bone marrow. RBCs have a short life span and must be continually replaced. The rate of production of RBCs is stimulated by the hormone erythropoietin, which is produced in the kidneys.

White blood cells defend the body

- White blood cells are larger than red blood cells they are also more diverse in structure and function. They have a nucleus but no hemoglobin.
- There are two major categories of white blood cells: granular leukocytes and agranular leukocytes.
  - Both types contain granule in their cytoplasm that are filled with proteins and enzymes to assist their defensive work.

- Granular leukocytes:
  - Neutrophils: the first white blood cells to combat infectio. Neutrophils surround and engulf foreign cells.
  - Eosinophils: defend the bodu against large parasites such as worms. The second function of eosinophils involves releasing chemicals that moderate the severity of allergic reactions.
  - Basophils: the granules in the cytoplasm of basophils contain histamine, a chemical that initiates the inflammatory response.

- Agranular leukocytes:
  - Monocytes: they can filter out of the blood stream and take up residence in body tissues, where they differentiate into the macrophages that engulf incaders and dead cellular debris by phagocytosis. They also stimulate lymphocytes to defend the body.
  - Lymphocytes: they are found in the bloodstream, tonsils, spleen, lymph nodes, and thymus gland.
    - T lymphocytes: target and destroy specific threats such as bacteria, viruses and cancer cells
    - B lymphocytes: give rise to plasma cells that produce antibodies specialized proteins that defend against microorganisms and other foreign invaders.

Platelets are essential for blood clotting

- Platelets are derived from megakaryocytes, which are large cells derived from stem cells in the bone marrow.
- Megakaryocytes never circulate, the remain in the bone marrow
- Platelets are just small pieces of megakaryocyte cytoplasm and cell membrane. Because platelets are not living cells, they last only about 5 to 9 days.

2. Hemostasis: stopping blood loss

- Hemostasis: the natural process of stopping the flow or loss of blood, proceeds in three stages:
  - Vascular spasm or intense contraction of blood vessels in the area
  - Formation of a platelet plug
  - Blood clotting, also called coagulation.

> - Hemostasis is a three-phase process that prevents blood loss through damaged vessels. The phases are (1) vascular spasm, (2) the formation of a platelet plug, and (3) blood clotting.
> - During the formation of a blood clot, substances released by damaged blood vessels cause soluble proteins threads called fibrin. The threads form a interlocking mesh of fibers, trapping blood cells and sealing ruptured vessels.

Vascular spasms constrict blood vessels to reduce blood flow

- When a blood vessel is damaged, smooth muscle in its wall undergoes spasms.
- If the vessels are small, the spasms press the inner walls together and may even stop the bleeding entirely.

Platelets stick together to seal a ruptured vessel

- Platelets circulate freely in blood.
- However the lining of a blood vessels breaks, exposing underlying proteins in the vessel wall, platelets swell, develop spiky extensions and begin to clump together.

Recap: white blood cells (leukocytes) defend the body against disease and injury. The activities of various leukocytes include participating in the response to tissue injury, producing antibodies, engulfing entire foreign cells, and releasing enzymes to attack foreign organisms too large to be engulfed whole.

A blood clot forms around the platelet plug

- Damage to blood vessels stimulates the vessels and nearby platelets to release prothrombin activator. → this activates the conversion of prothrombin, a plasma protein into an enzyme called thrombin.
- Thrombin in turn facilitates the conversion of a soluble plasma protein, fibrinogen, into long insoluble treads of a protein called fibrin.
- The mass of fibrin, platelets and trapped red blood cells coalesces into an initial clot that reduces the flow of blood at the site of injury
- Hemophilia: an inherited condition caused by deficiency of one or more clotting factors.

Recap: damage to blood vessels causes the vessels to spasm (contract) and the nearby platelets to become sticky and adhere to each other, limiting blood loss. In addition, a series of chemical events causes the blood in the area to clot, or coagulate (form a gel).

3. Human blood types

- Antigen is a nonself cell protein that stimulates the immune system of an organism to defend the organism.
- As part of this defense, the immune system produces an opposing protein called an antibody.

- Successful transfusion of blood form one person into another depends on compatibility of their blood types, which is determined by antibodies in plasma and surface antigens on red blood cells.
- Blood types are classified primarily on the basis of the ABO system and the presence or absence of the Rh factor.
- Rh factor in particular can affect certain pregnancies adversely.

Recap: different blood types are determined by the presence of surface antigens on red blood cells and the presence of antibodies to surface antigens other than their own.

ABO blood typing is based on A en B antigens

- Type A → A antigens
  → B antibodies
- Type B → B antigens
  → A antibodies
- Type AB → both A and B antigens
  → no antibodies
- Type O → no antigens
  → both A and B antibodies.
- These antibodies attack red blood cells with foreign antigens, damaging them and causing them to agglutinate or clump together.
- Any adverse effect of a blood transfusion is called a transfusion reaction.

Recap: Types A, B, AB, and O blood are indentified by the presence (or absence) of type A and/or B surface antigens on their red blood cells.

Rh blood typing is based on Rh factor

- Rh positive: carry the RH antigen on their red blood cells
- Rh negative: don't have the antigen, and consequently their immune systems respond to any foreign Rh antigen by making antibodies against it.
- Hemolytic disease of the newborn (HDN) a disorder characterized by a reduced number of red blood cells and toxic levels of hemoglobin breakdown products in the newborn (FIG 7.13 p 156 !!!)

Blood typing and cross-matching ensure blood compatibility

- Bloodtyping involved determining your ABO type and the presence of absence of the Rh factor.
- AB+ individuals were once called universal recipients because they can generally receive blood from any other type.
- Type O individuals were formerly called universal donors because their blood can usually be donated to any other type.
- Cross-matching involves small samples of donor blood with recipient plasma, and recipient blood with donor plasma and examining both combinations for agglutination.

Recap: in addition to ABO type, all persons are classified according to the presence or absence of another red blood cell surface antigen called the Rh factor. Rh factor antibodies can cause a serious immune reaction of the mother to her own fetus under certain circumstances.

4. Blood disorders

- Anemia is a reduction in blood oxygen-carrying capacity for any number of reasons, including insufficient red blood cell production and excessive blood loss.
- Leukemia is a cancer characterized by uncontrolled production of abnormal leukocytes (whit blood cells).
- Mononucleosis is a contagious viral disease of lymphocytes and lymphatic tissue.
- Blood poisoning is a general term for infection of blood plasma by various microorganisms.

Blood poisoning: infection of blood plasma

Mononucleosis: contagious viral infection of lymphocytes

- × Mononucleosis; a contagious infection of lymphocytes in blood and lymph tissues by the Epstein-Barr virus, a relative of the viruses that causes Herpes.
- × Symptoms: fever, headache, sore throat, fatigue, swollen tonsils and lymph nodes.

Anemia: reduction in blood's oxygen-carrying capacity

- × Anemia is a general term for reduction in the oxygen carrying capacity of blood.
- × symptoms: pale skin, headaches, fatigue, dizziness, difficulty breathing, and heart palpitations.
    - o Iron-deficiency anemia:
    - o Hemorrhagic anemia:
    - o Pernicious anemia:
    - o Hemolytic anemia:

Leukemia: uncontrolled production of white blood cells

- × Leukemia: refers to any of several types of blood cancer. Their common characteristic is uncontrolled proliferation of abnormal or immature white blood cells in the bone marrow.
- × There are two major categories of leukemia:
    - o Acute: which develops rapidly.
    - o Chronic

      →both are thought to originate in the mutation of a white blood cell that results in uncontrolled cell division, producing billions of copies of the abnormal cell.
- × Causes: viral infection, exposure to radiation or harmful chemicals, genetic factors.
- × Symptoms: tissues may bruise easily, anemia may develop, bones may feel tender, headaches, enlarged lymph nodes.

Multiple myeloma: uncontrolled production of plasma cells

- Multiple myeloma is a type of cancer.
- Abnormal plasma cells in the bone marrow undergo uncontrolled division.

Recap: Iron deficiency or hemorrhage, among other factors, can reduce the oxygen-carrying capacity of blood and result in anemia. Leukemia and multiple myeloma are blood cell cancers. They arise as abnormal cells in the bone marrow multiply in huge numbers.

Thrombocytopenia: reduction in platelet number

- Thrombocytopenia: is a reduction in the number of platelets in the blood.
- Causes: viral infection, anemia, leukemia, other blood disorders, exposure to Xrays or radiation and even as a reaction to certain drugs.
- Symptoms: easy bruising or bleeding, nosebleeds, bleeding in the mouth, blood in urine, and heavy menstrual periods.

Heart and blood vessels

- Cardiovascular system: the heart and blood vessels.
- The heart provides the power to move the blood, and the vascular system represents the network of branching conduit vessels through which the blood flows.

1.Blood vessels transport blood

- Blood vessels can be classified into three major types:
  - Arteries: thick-walled arteries transport blood to body tissues under high pressure.
  - Capillaries: micro-scopic capillaries participate in exchanging solutes and water with the cells of the body.
  - Veins: thin-walled veins store blood and return it to the heart.

- The primary function of blood vessels is to bring blood into close proximity with all living cells.
- Thick-walled arteries transport blood to the capillaries at high pressure.
- Small arterioles and precapillary sphincters regulate the flow of blood into each capillary.
- Thin-walled capillaries are the only vessels that exchange fluids and solutes with the interstitial fluid.
- Distensible venules and veins store blood at low pressure and return to the heart.

Arteries transport blood away from the heart

- Arteries transport blood away from the heart.
- The larger arteries have a thick layer of muscle because they must be able to withstand the high pressures generated by the heart.
- The vessel wall is a sandwich of three distinct layers surrounding the lumen or hollow interior of the vessel:
  - The thin inner layer, the endothelium. Is a layer of flattened squamous epithelial cells.
  - Just outside the endothelium is a layer composed primarily of smooth muscle with interwoven elastic connective tissue.
  - The outermost layer of large and medium-size arteries consists of a tough supportive layer of connective tissue, primarily collagen.

- The fact that arteries are constantly under high pressure places them art risk of injury.
  - Aneurysm (or ballooning of the artery wall): is the result if the endothelium becomes damaged, blood may seep through the injured area and work its way between the two outer layers, splitting them apart.
  - Sometimes aneurysms → severe chest pain. But in other cases they are completely symptomless until they rupture of "blow out", causing massive internal bleeding and often death.

Arterioles and precapillary sphincters regulate blood flow

Recap: A branching system of thick-walled arteries distributes blood to every area of the body. Arterioles regulate blood flow to local regions, and precapillary sphincters at the ends of arterioles regulate flow into individual capillaries.

Capillaries: where blood exchanges substances with tissues

- Capillaries: the smallest blood vessels.
  - Thin walled vessels, they are not much wider than the red blood cells that travel through them.
- Capillary beds: extensive networks of capillaries.
  - Can be found in all areas of the body.
  - Their thin, porous walls allow blood to exchange oxygen, carbon dioxide, nutrients and waste products with tissue cells.
  - Capillary walls consist of a single layer of squamous epithelial cells.
- Capillaries are the only blood vessels that can exchange materials with the interstitial fluid.

Lymphatic system helps maintain blood volume

- Lymphatic capillaries: is a system of blind-ended vessels which picks up the excess plasma fluid. It branches out throughout our body tissues and are part of the lymphatic system.
- Lymphatic system: also picks up a few objects in the interstitial fluid that are too large to diffuse into capillaries.
- Lymphatic capillaries transport the excess interstitial fluid and other objects to larger lymphatic vessels, which eventually returns the fluid (called lymph) to veins near the heart.

Recap: Capillaries consisting of a single layer of cells are the only blood vessels that can exchange materials with the interstitial fluid. The lymphatic system removes excess fluid.

Veins return blood to the heart

Recap: the thin-walled veins return blood to the heart and serve as a volume reservoir for blood. Return of blood to the heart is assisted by (1) contractions of skeletal muscles, (2) one-way valves inside veins, and (3) pressure changes associated with breathing.

2. The heart pumps blood through the vessels

- The heart is composed primarily of cardiac muscle. Structurally, it consists of four separate chambers and four one-way valves. Its primary function is to pump blood.
- The heart pumps blood simultaneously through two separate circuits: the pulmonary circuit, where blood picks up oxygen and gets rid of carbon dioxide, and the systemic circuit, which supplies the rest of the body's cells.
- The heart contracts and relaxes rhythmically. Contraction is called systole, and relaxation is called diastole.
- The coordinated contraction of the heart is produced by as a system of specialized cardiac muscle cells that initiate and distribute electrical impulses throughout the heart muscle.
- An electrocardiogram, or ECG, records electrical activity of the heart from the surface of the body. And ECG can be used to diagnose certain cardiac arrhythmias and disorders.

The heart is mostly muscle

- Pericardium: a fibrous sac that encloses the heart
  - Protects the heart
  - Anchors the heart to surrounding structures
  - Prevents it from overfilling with blood.
- Pericardial cavity: a space that separates the pericardium from the heart.
  - Contains a film of lubricating fluid that reduces friction
  - allows heart and the pericardium to glide smoothly against each other when the heart contracts.
- The walls of the heart consist of three layers:
  - Epicardium: the outermost layer. A thin layer of epithelial and connective tissue.
  - Myocardium: the middle layer. A thick layer consisting mainly of cardiac muscle that forms the bulk of the heart. It's the layer that contracts every time the heart beats.
  - Endocardium: the innermost layer of the heart. Is a thin endothelial layer resting on a layer of connective tissue. The endocardium is continuous with the endothelium that lines the blood vessels.
  - Occasionally one of the layers of the heart wall becomes inflamed. Pericarditis → inflammation of the pericardium . endocarditis→ inflammation of the endocardium.

Recap: The heart wall consists of three layers. The outer epicardium is a thin layer of epithelial and connective tissue; the middle myocardium consists largely of cardiac muscle and is the layer that contracts. The inner endocardium is a layer of endothelium continuous with the endothelium lining blood vessels.

The heart has four chambers and four valves

- Arteria: the two chambers on the top
- Ventricles: two more muscular bottom chambers
- Septum: a muscular partition that separates the right and the left sides of the heart.
- Blood returning to the heart from body tissues→ right atrium→ blood passes through a valve into the right ventricle → pumps the blood through a second valve into the artery → lungs.
- Blood returning from the lungs to the heart → left atrium → passes through a third valve in to the left ventricle → pumps the blood through a fourth valve → aorta →blood travels through arteries and arterioles to the systemic capillaries, venules, and veins → then back to the right atrium again.
- The valves open and shut passively in response to changes in the pressure of blood on each side of valve.
    - The right and left atrioventricular valves located between the atria and their corresponding ventricle prevent blood from flowing back into the atria when the ventricles contract.
    - Two semilunar valves prevent black flow into the ventricles from the main arteries leaving the heart when the heart relaxes.

Recap: The heart is composed of primarily of cardiac muscle. It contains four chambers that pump blood to the lungs and the rest of the body simultaneously. Four one-way valves permit blood flow in one direction only.

The pulmonary circuit provides for gas exchange

- Note: The heart is pumping blood through the lungs (the pulmonary circuit) and through the rest of the body to all the cells (the systematic circuit)
- The pulmonary circuit:
    - When blood returns to the heart from the veins → right atrium. The blood that returns to the heart is deoxygenated.
    - From right atrium → the right atrioventricular valve → right ventricle
    - The right ventricle pumps blood → pulmonary semilunar → the pulmonary trunk (lungs)
    - At the pulmonary capillaries, blood gives up carbon dioxide and receives a fresh supply of oxygen from the are we inhale.
    - The oxygenated blood flows into the pulmonary veins → heart. Left atrium → left atrioventricular valve → left ventricle
    - The desoxygenated blood in the right side of the heart never mixes with oxygenated blood in the left. Desoxygenated blood leaving the right side must pass through the pulmonary circuit before it reaches the left side of the heart.

The systemic circuit serves the rest of the body

- When the blood enters the left ventricle, it begins the systemic circuit which takes it to the rest of the body:
  - The left ventricle pumps the blood → aortic semilunar valvsye→ aorta
  - From the aorta blood travels → braching ateries and arterioles → the capillaries (where it delivers oxygen and nutrients)
  - From the capillaries blood flows → venules, veins → right atrium

- Coronary arteries: the heart has its own set of blood vessels that supply the heart muscle
- Cardiac veins: collect the blood from the capillaries in the heart muscle and channel it back to the right atrium

Recap: the right side of the heart (right atrium and right ventricle) pumps blood to the lungs, where blood is oxygenated and carbon dioxide is removed. The left side of the heart (left atrium and left ventricle) pumps blood to the rest of the body, supplying nutrients and removing wastes.

The cardiac cycle: the heart contracts and relaxes

- Systole: the period of contraction
- Diastole: the period of relaxation
- Cardiac cycle: the entire sequence of contraction and relaxation.
  - Atrial systole : as the contraction starts the heart is already filled with blood that entered the ventricles and atria passively during the previous diastole.
  - Ventricular systole: the contraction that began in the atria spreads to the ventricles, and both ventricles contract simultaneously. The rapidly rising ventricular pressure produced by contraction of the ventricles causes the two AV valves to close, preventing blood from flowing backward into the atria and veins. At this time the atria relax and begin filling again. The pressure within the ventricles continues to rise until it is greater than the pressure in the arteries, at which point the pulmonary and aortic semirural valves open and blood is ejected into the pulmonary trunk and the aorta. With each ventricular systole, about 60 procent of the blood I each ventricle is forcibly ejected.
  - Diastole:
  - Both atria and both ventricles are relaxed throughout diastole. At this point pressure within the ventricles begins to fall. As soon as ventricular pressure falls below arterial pressures during early diastole, the pulmonary and aortic semilunar valves close, preventing blackflow of aterial blood. Once ventricular pressure falls below blood pressure in the veins, the AV valves open and blood begins to flow passively into the heart.

Heart sounds reflect closing heart valves

- Heart sounds: reflect events that occur during the cardiac cycle. (specifically the closing the heart valves)
- The 'lub'signals the closure of the two AV valves during ventricular systole. The louder "DUB" occurs when the aortic and pulmonary semilunar valves close during ventricular diastole.
- Murmurs: result from incomplete closing of the heart valves due to unusually shaped valve flaps or stiffening of the flap tissue.

Recap: each cardiac cycle is a repetitive sequence of contractions (systole) and relaxation (diastole). The familiar "lub-DUB"of the heart beat is caused by the closing of the heart valves during the cycle.

Cardiac conduction system coordinates contraction

- Cardiac conduction system: a group of specialized cardiac muscle cells that initiate and distribute electrical impulses throughout the heart.
- The cardiac conduction system consists of 4 structures:
  - The sinoatrial (SA) node: the stimulus start a heartbeat and begins in the SA node. A small mass of cardiac muscle cells located near the junction of the right artrium and the superior vena cava.
  - The artrioventricular AV node: the electrical impulse traveling across the atria eventually reaches another mass of muscle cells the AV node. Located between the atria and ventricles.
  - From the AV node, the electrical signal sweeps to a group of conducting fibers in the septum between the two ventricles called the atrioventricular (AV) bundle. These fibers branch and extend into Purkinje fibers.
    - Purkinje fibers: smaller fibers that carry the impulse to all cells in the myocardium of the ventricles

Electrocardiogram records the heart's electrical activity

- ECG or EKG: is a record of the electrical impulses in the cardiac conduction system.
- Arrhythmia: an abnormality of the rhythm or rate of the heartbeat
- Ventricular fibrillation: a type of rapid irregular ventricular contraction → very quickly fatal unless treated immediately.

Recap: Contraction of the heart is coordinated by modified cardiac muscle cells that initiate and transmit electrical impulses through a specialized conduction system. An electrocardiogram (ECG) is a recording of the heart's electrical activity taken from the surface of the body.

3. Blood exerts pressure against vessel walls

- × Blood pressure is the force that blood exerts on the wall of a blood vessel as a result of the pumping action of the heart.
- × Blood pressure is not the same in all blood vessels.
- × Systolic pressure: The highest pressure if the cycle, is the pressure reached during ventricular systole when the ventricles contract to eject blood from the heart
- × Diastolic pressure: the lowest pressure occurs during ventricular diastole when the ventricles relax

- The heart generates blood pressure, and the arteries store the blood under pressure during diastole.
- Systolic and diastolic arterial blood pressures can be measured with a sphygmomanometer.
- High blood pressure, called hypertension, is a major risk factor for cardiovascular disease.

Measuring blood pressure

- × Systolic pressures of less than 120 mm Hg and diastolic pressures of less than 80 mm.
- × Blood pressure is measured with a sphygmomanometer.

Hypertension: high blood pressure can be dangerous

- × Hypertension: blood pressure higher than normal
- × Is called the silent killer because usually it has no symptoms.
- × What causes hypertension? Many times it happens because blood vessels become narrowed from atherosclerosis.
- × True hypertension is a sustained elevation in blood pressure above normal levers.
- × Sometimes systolic pressure can register at above normal levels while diastolic pressure remains normal, a condition called isolated systolic hypertension.

Hypotension: when blood pressure is too low

- × Hypotension: blood pressure that falls below normal levels.

Recap: blood pressure is the force the blood exerts on the wall of a blood vessel. It is measured as two numbers corresponding to systolic and diastolic pressures. Hypertension (high blood pressure) is a serious risk factor for cardiovascular diseases and other health problems.

4. How the cardiovascular system is regulated

The human cardiovascular system is based on similar principles:

a. Homeostatic regulation of the cardiovascular system centers on maintaining a constant arterial blood pressure.
b. A constant arterial blood pressure is achieved by regulating the heart rate and force of contraction and by regulating the diameters of all the body's arterioles as a whole
c. With arterial blood pressure held relatively constant, local blood flows are adjusted to meet local requirements

- The most important controlled variable in the cardiovascular system is arterial blood pressure.
- Arterial blood pressure is monitored by stretch receptors located in certain large arteries.
- Cardiac output and the diameters of the arterioles are regulated (controlled) to keep arterial blood pressure relatively constant.
- With pressure held constant, local blood flows can be adjusted according to the metabolic needs of the tissues and cells in that area of the body.

Baroreceptors maintain arterial blood pressure

- the baroreceptoors regulate arterial blood pressure in the following manner:
  - when blood pressure rises →arterial blood vessles are stretched passively
  - stretch of bareoreceptors in the carotid arteries and aorta causes them to send signals via nerves to an area of the brain called the cardiovascular center.
  - The cardiovascular center responds by sending signals via nerves to the heart and the blood vessels.
  - The effect on the heart is to lower the heart rate and force of contraction. This reduces cardiac output, the amount of blood that the heart pumps into the aorta each minute.
  - The effect on arterioles is vasodilatation, an increase in arteriole diameter. Vasodilatation increases blood flow through all tissues.
- The opposite sequence of events occurs when arterial pressure falls BELOW normal.
  - When pressure falls and the arteries stretch less than normal, the baroreceptors send fewer nerve signals to the brain. The brain correctly interprets this as a fall in pressure and sends the nerve signals that increase cardiac output and constrict arterioles, raising arterial blood pressure again.

Recap: Homeostatic regulation of the cardiovascular system centers on maintaining a relatively constant arterial blood pressure, making blood available to all cells as needed. Arterial pressure is sensed by barereceptors located in the carotid arteries and aorta.

Nerves and hormones adjust cardiac output

- We calculate cardiac output by multiplying heart rate by stroke volume
- Regulation of cardiac output in centered in an area of the brain called the medulla oblongata, which is where the cardiovascular center is located.
- Sympathetic nerves stimulate the heart and cause it to beat faster.
- Parasympathetic nerves inhibit the heart and cause it ti beat more slowly.
- The hormones epinephrine(= adrenaline) and norepinephrine stimulate the heart as well.

Local requirements dictate local blood flows

- How an increase in metabolism increases local blood flow
  - At rest, very little of the vasodilating substance would be produced, and flow would be minimal
  - With increased metabolic activity, the presence of more the substance in the interstitial space would cause the arteriole and precapillary sphincter to vasodilate, increasing flow.

Exercise: increased blood flow and cardiac output

- during exercise the metabolic activity of the active skeletal muscles goes up dramatically
- during exercise, the primary cause of increased cardiac output is sensory input from moving muscles and joints. this sensory input signals the cardiovascular center to stimulate the heart and increase cardiac output even before blood pressure can fall very much.
- → during exercise the body anticipates the need for increased cardiac output and prevents blood pressure from falling in the first place.
    - Lichaam anticipeert

Recap: The opposing sets of nerves (sympathetic and parasympathetic) and a hormone (epinephrine) adjust cardiac output and arteriole diameters to maintain arterial blood pressure. Local factors regulate blood flow into individual capillaries by altering the diameters of precapillary sphincters. During exercise, blood pressure is maintained by an increase in cardiac output caused primarily by sensory input from muscles and joints.

5. Cardiovascular disorders: a major health issue

- The heart muscle is always working. Impairment of blood flow to the heart can lead to a sense of pain and tightness in the chest (angina pectoris) and/or permanent damage to heart tissue (myocardial infarction, of heart attack).
- Slowly developing, chronic failure of the heart as a pump can lead to excessive interstitial fluid, a condition known as congestive heart failure.
- An embolism is the sudden blockage of blood vessel by any object.
- Strokes, also called cerebrovascular accidents, can be caused by either embolisms or rupture of blood vessels. The result is damage to a part of the brain when its blood supply is interrupted.

Angina: chest pain warns of impaired blood flow

- If arteries become narrowed, blood flow to the heart may not be sufficient for the heart's demands. This may lead to angina, a sensation of pain and tightness in the chest. Often angina is accompanied by shortness of breath and sensation of chocking of suffocating.

Heart attack: permanent damage to heart tissue

- Heart attack: if blood flows to an area of the heart is impaired long enough, sudden death of an area of heart tissue due to oxygen starvation.
- A heart attack causes permanent damage to the heart. Because the body cannot replace cardiac muscle cells, damage to the heart impairs its ability to function
- A coronary artery bypass graft: can be performed to improve coronary blood flow. In this procedure, a piece of blood vessel is removed from somewhere else in the body and grafted onto the blocked artery to bypass the damage.

Heart failure: the heart becomes less efficient

- Heart failure: if the heart muscle becomes damaged for any reason the heart may become weaker and less efficient at pumping blood.
- Congestive heart failure: the high capillary blood pressure causes more fluid than usual to filter out of the capillaries and into the interstitial space causing fluid congestion.

Embolism: blockage of a blood vessel

- Embolism refers to the sudden blockage of a blood vessel by material floating in the bloodstream.
    - Most often the obstacle (embolus) is a blood clot that has broken away from a lager clot elsewhere in the body.
        - Pulmonary embolism: blocks an artery suppling blood to the lungs → chest pain, shortness of breath
        - Cerebral embolism: impairs circulation to the brain → stroke
        - Cardiac embolism → heart attack

Stroke: damage to blood vessels in the brain

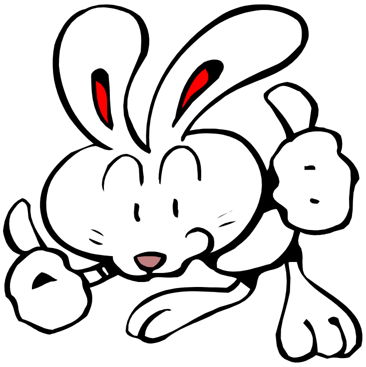
- Stroke: (cerebrovascular accident) represents damage to part of the brain caused by an interruption to its blood supply.
    - Symptoms of strokes appear suddenly and vary according to the area of the brain affected

Recap: Cardiovascular disorders are the number one killer in the U.S. Most disorders are caused either by conditions that result in failure of the heart as a pump of by conditions in which damage to blood vessels restrict flow or ruptures vessels.

6. Reducing your risk of cardiovascular disease

- Your chances of developing a cardiovascular disorder depend on certain risk factors. Some risk factors a you cannot change, whereas others depend on the choices you make in life.

× Don't smoke
× Watch your cholesterol levels
× Keep moving
× If your blood pressure is on the high side, seek treatment
× Maintain a healthy weight
× Keep diabetes under control
× Avoid chronic stress.



Je doet het fantastisch! goed zo! effe doorbijten en je kan 10 minuten dexter kijken !!
(speciaal voor Marjolein)

Recap: you can reduce your risk of developing cardiovascular disease by not smoking, exercising regularly, watching your weight and cholesterol, and avoid prolonged stress. If you have diabetes and/or hypertension, try to keep these conditions under control.

The immune system and mechanisms of defense

1. Pathogens cause disease

- Pathogens include bacteria, viruses, fungi, protozoa, worms, and possibly prions
- Bacteria have very little internal structure an are covered by a rigid outer cell wall.
- Viruses cannot produce on their own. Viral reproduction requires a living host cell.
- Prions are misfolded proteins that replicate by causing a normal protein to misfold.
- The danger from a particular pathogen depends on how it is transmitted, how easily it is transmitted, and how damaging the resulting disease is.

- pathogen = living organisms (such as bacteria) and nonliving entities (such as virusses and prions) that cause disease
  - our body protects itself in many different ways:
    - barriers to entry, or ways of expelling/neutralizing pathogens before they can do harm
    - skin, stomach acid, tears, vomiting, defacation
    - nonspecific defense mechanisms
    - specific defense mechanisms
- immune system = complex group of cells, proteins, and structures of the lympathic and circulatory systems → crucial to nonspecific and specific defense mechanisms!

Bacteria: single-celled living organisms

- bacteria = single-celled organisms that do not have a nucleus or membrane-bound organelles
  - the bacteria which are pathogens rely on living human cells for their energy supply → they damage or kill cells in the process of obtaining this energy
- antibiotics = chemotherapeutic agents used to treat bacterial infections by inhibiting or abolishing the growth of bacteria, fungi, and protozoa

Recap: Bacteria are single-celled organisms. Like all cells, they draw their energy and raw materials from their environment. Pathogenic bacteria get the materials they need from living cells, damaging or killing the cells in the process.

Viruses: Tiny infectious agents

- viruses = extremely small infectuous agents
  → structure: small piece of genetic material + protein coat. No organelles, can't grow or reproduce on their own.
- viruses have several ways of gaining entry into the cells:
  - being taken into cell plasma by endocytosis, viral genetic material released into cell's genetic material
  - merging outcer coat with cell membrane, releasing genetic contents into cell's cytoplasm
  - attach to outer surface of cell and inject genetic material

- product: cell begins to produce thousands of copies of the virus

Prions: Infectuous proteins

- prion = misfolded form of a normal brain cell protein → can trigger misfolding of nearby normal proteins as well!!
  - example: "mad cow disease"

Recap: A virus consists of a single strand of DNA or RNA surrounded by protein. Viruses use their DNA or RNA to force a living cell to make more copies of the virus. Prions are infectious proteins that cause normal proteins to misfold.

Transmissibility, mode of transmission, and virulence determine health risk

- tranmissibility = how easily the pathogen is passed from one person to another
- mode of transmission = how it is transmitted
- virulence = how damaging the resulting disease is
  - example: bubonic plague

- The lymphatic system consists of vessels, lymph nodes, the spleen, the thymus gland, and the tonsils
- The lymphatic system helps protect us against disease.
- Phagocytic cells in the spleen, lymph nodes, and tonsils engulf and kill microorganisms
- The thymus gland secretes hormones that help T lymphocytes mature.

2. The lymphatic system defends the body

- lymphatic system = closely associated with the cardiovascular system, performs three important functions:
- helps maintain volume of blood in cardiovascular system
- transports fats + fat-soluble vitamins from digestive system to cardiovascular system
- defends body against infection

basic components of the lympathic system:

- network of lymph vessels
- lymph nodes
- spleen
- thymus gland
- tonsils + adenoids

Lymphatic vessels transport lymph

lympathic capillaries (containing lymph) → lymphatic vessels → two marjor lympathic ducts (right lymphatic duct + thoracic duct) -→ subclavian veins (near shoulders)

Lymphatic vessels cleanse the lymph

- lymph nodes = small organs located at intervals along the lymphatic vessels → they remove micro-organisms, cellular debris, and abormal cells from lymph

Recap: The lymphatic systems helps protect us from disease. As lymph flows through the lymph nodes, macrophages and lymphocytes within the nodes identify microorganisms and remove them.

The spleen cleanses blood

- spleen = largest lymphatic organ → soft, fist-sized mass located in the upper-left abdominal cavity, controls quality of circulating red blood cells + fights infection

Thymus gland hormones caust T lymphocytes to mature

- thymus gland = located in the lower neck, behind the sternum, just above the heart → secretes two hormones, thymosin and thymopoietin, causes T lymphocytes to mature and take role in specific defenses

Tonsils protect the throat

- tonsils = masses of lymphatic tissue near the entrance to the throat → here, lymphocytes gather and filter out microorganisms
- tonsilitis = inflammation resulting from infected tonsils

Recap: The spleen removes damaged red blood cells and foreign cells from blood. The thymus gland secretes hormones that help T lymphocytes mature. Cells in the tonsils gather and remove microorganisms that enter the throat.

3. Keeping pathogens out: the first line of defense

- Skin is an effective barrier to the entry of microorganisms
- Tears, saliva, mucus, and earwax trap organisms and/or wash them away.
- Digestive acid in the stomach kills many microorganisms
- Vomiting, defecation, and urination physically remove microorganisms after entry.

Skin: An effective deterrent

skin has four key attributes that make it such an effective barrier:

- structure
  - outermost layers of skin's epidermis = dead, dried-out epithelial cells, resulting from keratin
- the fact that it is constantly being replaced
  - any pathogens deposited on the surface are shed along with dead cells
- acidic PH
  - a low (acidic) PH of 5 or 6 makes skin a hostile environment for many microorganisms
- production of an antibiotic by sweat glands
  - sweat glands produce dermicidin, a natural antibiotic peptide that can kill a range of harmful bacteria

Impeding pathogen entry in areas not covered by skin

most successful pathogens enter the body at places where we do not have skin, but even these places have ways to impede pathogen entry:

- tears, saliva, earwax
  - tears and saliva both contain lysozyme, an enzyme that kills many bacteria
  - earwax traps small particles and microorganisms
- mucus
  - thick, gel-like material secreted by cells at various surfaces of the body (lining of digestive tract, airways of respiratory system…)
  - cells of these airways have tiny hairlike projections (cilia) that beat constantly to sweep mucus upward into the throat
- digestive and vaginal acids
  - undiluted digestive acid is stong enough to killl most pathogens
  - vaginal secretions are also slightly acidic
- vomiting, urination, and defecation
  - vomiting is an effective way of ridding the body of toxic or infected stomach contents
  - urine is usually slightly acidic, constant flushing keeps bacterial populations low
  - movement of feces help remove microorganisms from the digestive tract
- resident bacteria
  - beneficial bacteria that live in the mucuous membranes lining the vagina and the digestive tract

Recap: Various mechanisms create an inhospitable environment for pathogenic microorganisms. Skin is a dry outer barrier. Tears, saliva, earwax, and mucus trap them or wash them away. Acidic conditions kill them or inhibit their growth; urination, defecation, and vomiting forcibly expel them; and resident bacteria compete with pathogens for food.

4. Nonspecific defenses: the second line of defense

- Phagocytes surround and engulf microorganisms and damaged cells
- Inflammation has four outward signs: redness, warmth, swelling, and pain.
- Natural killer cells kill their targets by releasing damaging chemicals.
- Circulating proteins of the complement system either kill microorganisms directly or mark them for destruction.
- Interferons are proteins that interfere with viral reproduction.
- Fever raises body temperature, creating a hostile environment for some microorganisms.

Phagocytes engulf foreign cells

- phagocytosis = a process where white blood cells, called phagocytes, destroy foreign cells
  - phagocyte captures bacteria → draws bacterium in + engulfs it in membrane-bound vesicle (endocytosis) → vesicle fuses with lysosomes → enzymes in lysosomes dissolve bacterial membranes → phagocystes gets rid of bacterial wastes (endocytosis)
- neutrophils = first white blood cells to respond to infection → digest and destroy bacteria + fungi in the blood and tissue fluids
- macrophages = engulf and digest large numbers of foreign cells (viruses, bacterial parasites...) + clean-up function + release of chemicals that stimulate white blood cell production
- eosinophils = white blood cells which cluster large parasites or foreign proteins that are too big to be destroyed through phagocytosis

Recap: Nonspecific defense mechanisms involve a general attack against all foreign and damaged cells. Neutrophils and macrophages engulf and digest bacteria and damaged cells. Eosinophils bombard larger organisms (too large to be engulfed) with digestive enzymes.

Inflammation

- inflammation (or inflammatory response) = triggered by tissue injury, has four outward signs: redness, warmth, swelling, and pain
- When tissues are injured, damaged cells release chemicals which stimulate mast cells, which are connective tissue cells specialized to release histamine, which promotes vasodilation of neighboring small blood vessels. (vasidolation = rush of blood to injured area)
- natural killer (NK) cells = white blood cells that destroy tumor cells and cells infected by viruses → nonspecific killers, release chemicals that break down their target's cell membranes

The complement system assists other defense mechanisms

- complement system = at least 20 plasma proteins that circulate in the blood and complement/assist other defense mechanisms → inactive unless activated by presence of infection

Interferons interfere with viral reproduction

- interferons = proteins secreted by cells that become infected by viruses → make it harder for viruses to infect protected cells nearby the infected cell

Fever raises body temperature

- fever = abnormally high body temperature, makes our internal environment less hospitable to pathogens

Recap: The inflammatory response attracts phagocytes and promotes tissue healing. Natural killes cells release chemicals that disintegrate cell membranes of tumor cells and virus-infected cells. The complement system assist other defense mechanisms, interferons interfere with viral reproduction, and a modest fever enhances our ability to fight infections.

5. Specific defense mechanisms: the third line of defense

- Cells of the immune system can distinguish foreign or damaged cells from our own healthy cells.
- All cells have cell-surface markers called MHC proteins that identify the cells as self
- An antigen is a substance that stimulates the immune system and provokes an immune response
- B cells produce antibodies against foreign antigens
- T cells of several types release chemicals that enhance the immune response and kill foreign cells directly.

- immune response = collective term for the activities of the immune system → specific defense mechanisms with specific targets
- the immune response has three important characteristics:
  - it recognizes + targets specific pathogens/foreign substances
  - is capable of storing information from past exposure so it can respond more quickly to later invasions by the same pathogen
  - it protects the entire body, not just the site of infection

The immune system targets antigens

- antigen = any substance that mobilizes the immune system and provokes an immune response → each antigen has a unique shape, and every bacterium/virus has a different one
- major histocompatibility complex (MHC) proteins = proteins on surface of cells, used by immune system to recognize that the cells belong to you (self markers) → usually they signal the immune system to bypass the "good" cells

Recap: An antigen is any substance that provokes an immune response. All cells of an organism have markers called MHC proteins that identify the cells as "self". Nonself MHC proteins are antigens, and as such they activate the immune system.

Lymphocytes are central to specific defenses

- lymphocytes play crucial roles in our defense mechanisms
- B cells/B lymphocytes = responsible for antibody-mediated immunity → B cells produce antibodies, which are proteins that bind with and neutralize specific antigens (protect us against vrisues, bacteria, foreign molecules that are soluble in blood/lymph)
- T cells/T lymphocytes = responsible for cell-mediated immunity → T cells do not produce antibodies, but instead directly attack forgign cells that carry antigens (protet us against parasites, bacteria, viruses, fungi, cancerous cells, cells perceived as foreign)

B cells: Antibody-mediated immunity

- as B cells mature in the bone marrow, they develop unique surface receptors that allow them to recognize specific antigens.
- B cell with specific surface receptor meets specific antigen → surface receptors bind to antigen → activates B cell to grow + multiply → the resulting identical cells/clones (= plasma cells) secrete antibodies into the lymph fluid and then into the blood plasma
- memory cells = clone cells, remain inactive for a long time until specific antigen reappears in body → basis for long-term immunity

Recap: Lymphocytes called B cells produce antibodies against specific antigens. When activated by first exposure to an antigen, B cells quickly produce a clone if identical antibody-producing B cells called plasma cells that remain inactivate until the next exposure to the same antigen.

The five classes of antibodies

- immunoglobins (Ig) = antibodies belonging to the class of blood plasma proteins called gamma globins → crucial role in immunity
- there are five classes of immunoglobins, each with a different size, location, and function:
- IgG (75% of immunoglobins)
  - found in blood, lymph, intsetines, tissue fluid
  - activate the complement system + neutralize many toxins
- IgM (5-10%)
  - found in blood and lymph
  - activate the complement system + cause foreign cells to agglutinate
- IgA (15%)
  - enter ares of the body covered by mucuous membranes (digestive, reproductive, respiratory tracts)
  - neutralize infectuous pathogens
- IgD (less than 1%)
  - found in blood, lymph, and B cells
  - function is not clear, but play role in activating B cells
- IgE (approx. 0.1%)
  - found in B cells, mast cells, and basophils
  - activate inflammatory response by triggering release of histamine

Antibodies' structure enables them to bind to specific antigens

- all antibodies → same basic structure: IgG antibody consisting of four linked polypeptide chains arranged in a Y shape, containing constant regions and variable regions
- variable regions = antigen-binding sites, each has a unigue shape that fits only one specific antigen

Recap: There are five classes of antibodies (also called immunoglobulins), each with a characterized size, shape, and function. Within each class, a particular antibody fits only one specific antigen.

T cells: cell-mediated immunity

- two basic functional diffferences between B cells & T cells:
  - B cells produce circulating antibodies ⇔ T cells either release chemicals that stimulate other cells of the immune system, or they directly attack and kill the foreign cell
  - T cell receptor cannot egognize whole antigens, only small fragments (antigen-processing must occur so cells can be presented)

- **antigen-presenting cells (APCs)** = cells that engulf foreign particles, partially digest them, and display fragments of the antigens on their surfaces → cell "presents" fragment for T cells to recognize along with its own cell-surface self marker
- **helper T cell** = T cell with CD4 receptors which has encountered an antigen-presenting cell displaying a fragment of an antigen → produce clones
- **cytokines** = class of signaling molecules, secreted by helper T cell clones
  - stimulate other immune cells (phagocytest, natural killer cells, T cells with CD8 receptors)
  - attract other types of white blood cells to the area, enhancing non-specific defenses
  - active B cells, creating important link between antibody-mediated and cell-mediated immunity

- **cytotoxic T cells (**killer T cells**)** = T cell clone that is produced when mature T cellw ith CD8 receptors meets an antigen-producing celll that displays an antigen fragment → cytotoxic T cells are the only T cells that directly attack and destroy other cells
- cytotoxic T cell locates and binds to a target cell → secretory vesicales release protein (perforin) into space between the two cells → perforin molecules assemble themselves into a pore in the target cell, allowing water + salts to enter → eventually this kills the cell, and just to make sure the cytotoxic T cell also releases a toxic enzyme called granzyme before leaving

Recap: Lymphocytes that mature in the thymus gland become T cells. Helper T cells enhance specific and nonspecific defenses by stimulating other immune cells. Cytotoxic T cells attack abnormal and foreign cells. Memory T cells store information until the next exposure to the same antigen.

6. Immune memory creates immunity

- Information about an antigen is stored in memory cells after first exposure
- The second exposure to the antigen produces a much greater immune response than the first
- The rapidity of the second response is the basis of immunity from disease

- first exposure to antigen → primary immune response, production + profileration of B and T cells
- subsequent exposure to pathogen → secondary immune response, more effective than the first and involves memory cells
- presence of memory cells = basis for **immunity** from disease

Recap: First exposure to a specific antigen generates a primary immune response. Subsequent exposure to the same antigen elicits a secondary immune response that is faster, longer lasting, and more effective.

7. Medical assistance in the war against pathogens

- Vaccines immunize the body in advance against a particular disease
- Injected antibodies provide temporary immunity and are of some benefit against an existing infection
- Monoclonal antibodies are used primarily in medical tests
- Antibiotics are effective against bacteria, but not against viruses

× **immunization** = active + passive methods of helping the body to resist specific pathogens → producing monoclonal antibodies, discovery of antibiotics

Active immunization: An effective weapon against pathogens

× **active immunization** = the process of activatin the body's immune system in advance → involves administering an antigen-containing preparation called a **vaccine** (created from weak or dead pathogens)

× but vaccines do have their limitations:
  - issues of safety, time, and expense
  - a different vaccine is needed for each new virus
  - vaccines can't cure an already existing disease

Passive immunization can help against existing or anticipated infections

× **passive immunization** = a procedure where the patient is given the antibodies that his/her own immune system might produce if there were enough time (if infection already exists)

Recap: Active immunization with a vaccine (a preparation of weakened or dead pathogens) produces a primary immune response and readies the immune system for a secondary immune response. Administration of prepared antibodies (passive immunization) can be effective against existing infections but does not confer long-term immunity.

Monoclonal antibodies: Laboratory-created for commercial use

× **monoclonal antibodies** = antibodies produced in the lab from cloned descendants of a single hybrid B cell → proving useful in research, testing, and cancer treatments...

× mouse immunized with antigen → B cells extracted from mouse's spleen → antibody-producing B cells fused with cancer cells → cells that produce desired antibody are selected → these cells are cloned → large numers of these cells are grown

Antibiotics combat bacteria

antibiotics take advantage of the natural differences between bacteria and human cells:

- bacteria have thick cell walls, human cells do not
- bacterial DNA is not safely enclosed in a nucleus, human DNA is
- bacterial ribosomes are smaller than human ribosomes
- bacterial rate of protein synthesis is very rapid as they grow and divide

Recap: Monoclonal antibodies are laboratory-produced antibody preparations that are specific tor a single antigen. Most antibiotics kill bacteria by interfering with bacterial protein synthesis or bacterial cell wall synthesis.

8. Tissue rejection: a medical challenge

- The phenomenon of tissue rejection is a normal consequence of the body's ability to recognize self from nonself
- Immunosuppressive drugs, the ability to test for various antigens, and organ donor matching programs have increased the success rate of organ transplantation in humans

tissue rejection = a phenomenon where the immune system attacks foreign human tissues with vigor → cause many tissue transplants to fail

in recent years, three factors have made organ transplants a viable option for many people:

- improvements in immuno-suppressive drugs
- better techniques for cross-matching tissue
- national sharing of information and donor organs through organ-bank systems

Recap: The major obstacle to organ transplantation is the recipient's immune response, as cytotoxic T cells usually attack all foreign cells.

9. Inappropriate immune system activity causes problems

- Allergies occur when the immune system responds excessively to foreign particles that are not otherwise harmful
- Autoimmune disorders develop when a person's immune system attacks the person's own cells as if they were foreign

Allergies: A hypersensitive immune system

allergy = inappropriat respone of the immune system to an **allergen** (= any substance that causes an allergic reaction) → the allergen is not a dangerous pathogen, but the body reacts as if it were

symptoms of a sever systemic allergic reaction (anaphylactic shock):

- difficulty breathing
- severe stomach cramps
- swelling throughout the body
- circulatory collapse with a life-threatening fall in blood pressure

> *Recap: An allergy is an appropriate inflammatory response. Allergens that produce a systemic response can rapidly affect the ability to breathe and maintain blood pressure.*

The respiratory system: exchange of glases

1. Respiration takes place throughout the body

- Respiration encompasses four processes: breathing, external respiration, internal respiration, and cellular respiration
- External respiration occurs in the lungs; internal respiration and cellular respiration take place in the tissues.

the primary function of the **respiratory system** is to exchange gases (oxygen and carbon dioxide) with the air

the term respiration encompasses four processes:

- breathing (**ventilation**)
  - movement of air into and out of the lungs
- external respiration
  - exchange of gases between inhaled air and blood
- internal respiration
  - exchange of gases between blood and tissue fluids
- cellular respiration
  - the process of using oxygen to produce ATP within cells
  - generates carbon dioxide as a waste product

2. The respiratory system consists of upper and lower respiratory tracts

- The respiratory system includes the air passageways to the lungs and the lungs themselves
- Bones and skeletal muscles support the respiratory system and participate in breathing
- The upper respiratory tract consists of the nose and pharynx. The upper respiratory tract filters, warms, and humidifies the air we breathe
- The lower respiratory tract consist of the larynx, the trachea, the main bronchi, and the lungs
- Within the lungs, the bronchi branch many times, becoming smaller airways called bronchioles that end in air filled sacs called alveoli.
- The tremendous surface area of the alveoli, coupled with the thinness of the respiratory membrane, facilitates gas exchange with pulmonary capillaries.

the respiratory system = a system of passageways for getting air to and from the lungs + the lungs themselves, where gas exchange actually occurs

→ divided into the upper & lower respiratory tracts

upper respiratory tract:	lower respiratory tract:
nose (nasal cavity) pharynx	larynx trachea the two bronchi (branch from the trachea) the lungs

The upper respiratory tract filters, warms, and humidifies air

the nose:

- passageway for respiration
- contains receptors for sense of smell
- filters inhaled air, screens out foreign particles
- moistens + warms incoming air
- resonating chamber, gives voice its characteristic tone

external nose = the visib

le portion of the nose

- cartilage in the front, two nasal bones behind the cartilage

nasal cavity = the internal portion of the nose

- lined with moist epithelial tissue that is well supplied with blood vessels, both aid in warming and moisturizing the air
- cilia, tiny hairlike projections, line the epithelium, beat mucus around the cavity and throat

incoming air next enters the **pharynx** (throat), which connects the mouth and nasal cavity to the larynx

- the upper pharynx extends from the nasal cavity to the roof of the mouth
- into the upper pharynx open the two auditory tubes → drain the middle ear cavities + equalize air pressure between middle ear and outside ear

Recap: The respiratory system is specialized for the exchange of oxygen and carbon dioxide with the air. The upper respiratory tract filters, warms, and humidifies the air.

The lower respiratory tract exchanges gases

lower respiratory tract:

- larynx
- trachea
- bronchi
- lungs → bronchiloes + alveoli

larynx = voice box, extend for about 5 cm below pharynx

- maintains open airway
- routes food + air into the appropriate channels
- assists in production of sound

contains two important structures:

- **epiglottis**: flexible flap of cartilage located at the opening to the larynx
    - o "switching mechanism," routs food and beverages into the esophagus and digestive system
- **vocal cords**: two folds of connective tissue that extend caross the airway → surround the opening of the airway (the **glottis**)
    - o most sounds are produce by vibration of the vocal courds

trachea = the "windpipe," extends from larynx to the left and right bronchi → consists of a series of C-shaped, incomplete rings of cartilage, held together by connective tissue and muscle

- ring of cartilage keep trachea open at all times
- trachea also lined with cilia-cover epithelial tissue that secretes mucus
- choking can stimulte receptors in the throat that trigger the cough reflex

the trachea branches into two airways, the right and left **bronchi**, as it enters the lung cavity the bronchi:

- divide into a network of smaller and smaller bronchi
- walls of bronchi contain fibrous connective tissue and smooth muscle reinforced with cartilage
- progressively smaller airways → progressively less cartilage

bronchioles = the smallest airways, lack cartilage

bronchi + bronchioles have several functions:

- air transport
- clean the air
- warm air to body temperature
- saturate air with water vapor

the lungs = organs consisting of support tissue enclosing the bronchi, bronchioles, blood vessels, and areas where gas exchange occurs → each lung is enclosed in two layers of thin epithelial membranes (the **plural membranes**)

lungs consist of several lobes, three in the right lung and two in the left, each containing a branching tree of bronchioles and blood vessels

alveoli = tiny air-filled sacs at the end of the branching bronchioles → gas exchange takes place in the alveoli

Recap: The larynx maintains an open airway, routes food and air into the appropriate channels, and produces sound. Sound is produced by vibration of the vocal cords as air passes through the glottis.

Recap: The trachea, or windpipe, branches into the right and left bronchi, which further subdivide into smaller bronchi and then bronchioles. Like other areas of the respiratory tract, the bronchi and bronchioles filter, warm, and humidify the incoming air before it reaches the gas exchanges structures in lungs.

Recap: The lungs are organs containing a branching system of bronchi an bronchioles, blood vessels, and 300 million alveoli and pulmonary capillaries.

3. The process of breathing involves a pressure gradient

- Inspiration occurs as the lungs expand due to the action of the diaphragm and the intercostals muscles; expiration occurs when these muscles relax
- When the lungs expand, the pressure within them falls relative to atmospheric pressure and air rushes in; during expiration, the lungs become smaller and increasing pressure within them forces air out.
- During normal breathing, inspiration is active (requiring energy) and expiration is passive
- Normally we breathe at about 12 breathes per minute with a tidal volume of 500 ml per breath
- Vital capacity is the maximum amount of air a person can exhale after a maximal inhalation

breathing → air in and out of lungs in cyclic manner, requires muscular effort

diaphragm = main muscle of respiration, a broad sheet of muscle that seperates the thoracic cavity from the abdominal cavity

Inspriation brings in air, expiration expels it

general prinicples of gas pressure, how gases move:

- gas pressure is caused by collidign molecules of gas
- volume of a closed space increases → gass pressure decreases
- volume of a closed space decreses → gas pressure increases
- gases flow from areas of higher pressure to areas of lower pressure

inspiration pulls aire into the respiratory system as lung volume expands

expiration pushes air out as lung volume declines again

cyle of inspiration and expiration:

1. relaxed state → both diaphragm and intercostal muscles are relaxed
2. inspiration → diaphragm contacts and intercostal muscles contract, increasing the volume of the pleural cavity + lowering the pressure within the pleural space
3. expiration → muscle contractions end, the muscles relax and return to their normal position, pleural cavity becomes smaller (so pressure rises)

Recap: Inspiration is an active process (requiring energy) that occurs when the diaphragm and intercostal muscles contract. Normally expiration is passive, but it can become active when we forcibly exhale, cough, or sneeze.

Lung volumes and vital capacity measure lung function

each breath represents a **tidal volume** of air → about 500m

vital capacity = the maximal volume you can exhale after a maximal inhalation → about 4800 m

Recap: Although we normally take breaths of about 500 ml (tidal volume), our vital capacity is about 4,800 ml. Some air, called the residual volume, remains in the lungs even at the end of expiration.

4. Gas exchange and transport occur passively

- The diffusion of a gas is dependent on a partial pressure gradient, which is equivalent to a concentration gradient
- External and internal respiration are both processes that occur entirely by diffusion
- Nearly all (98%) of the oxygen transported by blood is bound to hemoglobin in red blood cells
- Although some carbon dioxide is transported as dissolved CO^2 or is bound to hemoglobin, most CO^2 (70%) is converted to bicarbonate and then transported in plasma

Gases diffuse according to their partial pressures

In a mixture of gases, each gas exerts a **partial pressure**, proportional to its precentage of the total gas composition (respresented by P, measured in mm Hg/mercury)

changes in partial pressure are entirely responsible for the exchange and transport of gases between the alveoli and the blood and between the blood and the tissues

External respiration: The exchange of gases between air and blood

when deoxygenated blood arrives at the pulmonary capilaries from the pulmonary arteries, oxygen diffuses from the alveoli into the capillaries, and carbon dioxide diffuses in the opposite direction

Internal respiration: The exchange of gases with tissue fluids

blood enters the capillaries → oxygen diffuses from the capillaries into the interstitial fluid → replenishes oxyen used by cells

carbon dioxide diffuses in the opposite direction (rom the cell into the interstitial fluid, and then into the capillary blood)

Recap: In a mixture of gases such as air, each gas exerts a partial pressure. Gases diffuse according to differences in their partial pressures. Diffusion accounts for both external and internal respiration.

Hemoglobin transports most oxygen molecules

oxygen is transported in bood in two ways: either is bound to hemoglobin (Hb) in red blood cells, or it is dissolved in blood plasma

hemoglobin = large protein molecule consisting of four polypeptide chains, each associated with an iron-containing heme group that can bind oxygen

oxyhemoglobin = hemoglobin molecule binded with four oxygen molecules

Recap: Nearly all of the oxygen in blood is bound to hemoglobin in red blood cells. Most carbon dioxide produced in the tissues is transported in blood plasma as bicarbonate.

5. The nervous system regulates breathing

- A respiratory center in the medulla oblongata of the brain establishes a regular cycle of inhalation and exhalation
- Under normal conditions, the rate and depth of breathing as adjusted primarily to maintain homeostasis of arterial blood Pco^2
- Regulation of respiration by o^2 comes into play only when the Po^2 concentration falls by more than 20%, such as in disease states of t high altitude
- We can exert some conscious control over breathing

A respiratory center establishes rhythm of breathing

respiratory center = groups of nerve cells in the medulla oblongata that automatically generate a cyclic pattern of electrical impulses every 4-5 seconds → stimulate the diaphragm and intercostal muscles to contract

Chemical receptors monitor CO2 , H+, and O2 levels

certain cells in the medulla oblongata can detect changes in the H+ concentration of the cerebrospinal fluid → rise in CO_2 concentration accompanied by a rise in the hydrogen ion concentration

Recap: The respiratory center in the brain establishes a regular pattern of cyclic breathing. The rate and depth of breathing are then adjusted by regulatory mechanisms that monitor arterial concentrations of CO^2, H+, and O^2. Conscious control can modify regulatory control but cannot override it completely.

6. Disorder of the respiratory system

- Asthma is episodic, spasmodic contractions of the bronchi that impede air flow
- Emphysema is a chronic disorder characterized by high resistance to air flow and destruction of alveoli
- The lungs are prone to infections because their surface is kept moist and warm in order to facilitate gas exchange. Tuberculosis, is an infectious disease caused by a bacterium. In pneumonia, infected alveoli secrete excess fluid, impairing gas exchange.
- Lung disease can be a secondary condition resulting from impairment of another organ, as in congestive heart failure.

asthma = characterized by spasmodic contraction of bronchial muscle, bronchial swelling, and increased production of mucus

an asthma attack causes partial clsure of the bronchi, making breathing difficult

symptoms:

- coughing while exercising
- shortness of breath
- wheezing
- sense of tightness in the chest

cystic fibrosis = an inherited condition in whice a single defective gene causes the mucud-producing cellls in the lungs to produce a thick, sticky mucus → the abnormally thick mucus impedes air flow and also provides a site for the growth of bacteria

colds → primarily caused by viruses of the rhinovirus or cornoavirus families

symptoms:

- coughing
- runny nose
- nasal congestion
- sneezing

flu → caused by viruses of the influenza family

symptoms:

- sore throat
- fever
- cough
- sometimes accompanied by aches, chills, muscle pains, headache

a pneumothorax = a collapse of one or more lobes of the lungs

most common cause: a penetrating wound of the chest → allows air into the pleural cavity around the lungs

can also occur spontaneously as the result of disease or injury to a lung

Recap: The lungs are prone to damage by environmental pollutants, tobacco smoke, and infections by microorganisms. Cases of both asthma and tuberculosis are on the rise.

~~The nervous system: integration and control~~

~~Sensory mechanisms~~

The endocrine system

1. The endocrine system produces hormones

endocrine system = collection of specialized cells, tissues, and glands that produce/secrete hormones

endocrine glands = ductless organs, secrete their products into interstitial fluid, lymph, blood

hormones = circulation chemical messenger molecules, secreted by the endocrine glands (specific hormones ⇔ specific functions)

endocrine system has certain characteristics that set it apart from the nervous system:

- hormones of the endocrine system reach nearly every living cell
  - hormones circulate in the blood, almost every cell in the body is near a blood vessel
- each hormone acts only on certain cells (**target cells**)
  - only the hormone's target cells have the appropratie receptor to fit it
  - when a hormone binds to a receptor on its target cell, a change occurs within the cell
  - all other cells fail to respond to the hormone -→ lack the appropriate receptor
- endocrine control tends to be slower than nervous system control
  - takes longer to secrete a hormone into the bloodstream, have the hormone reach its target, and exert its effect
  - endocrine communication is, however, effective for long longer-term controls (regulation of blood pressure, production of red blood cells, onset of puberty)
- the endocrine and nervous systems can ineract with each other
  - realease of some hormones depends on input from sensory neurons

2. Hormones are classified as steroid or nonsteroid

two basic categories of hormones:

- **steroid hormones:** structurally related to cholesterol → lipid soluble
  - enter the cell, bind to an intracellular receptor, activate genes that produce new proteins
- **non-steroid hormones:** structurally related to proteins → lipid insoluble
  - bind to the receptors on the cell's surface, initiate series of events that alters cellular activity in some way

→ the differences in lipid solubility explain their mechanisms of action

Steroid hormones enter target cells

cell membrane → bilayer of phospholipids

steroid hormones = lipid soluble

1. hormones diffuse across boh the cell membrane and the nuclear membrane
2. bind to specific hormone receptors, forming a hormone-receptor complex
3. hormone-receptor complex attachtes to DNA, activating specific genes
4. causes formation of messengr RNA
5. messenger RNA leaves nucles, driects sythesis of certain proteins
6. finally, the proteins carry out the hormone's cellular response

steroid hormones → slower in action than nonsteroid hormones

Nonsteroid hormones bind to receptors on target cell membranes

nonsteroid hormones = not lipid soluble

1. hormones bind to receptors on outer surface of cell membrane
2. the binding of hormone to receptor (usually part of protein molecule) causes chan in shape of membrane protein
3. initiates changes within the cell → converts inactive molecule within cell to an active molecule

activated molecule = **second messenger** → carries the message provided by the hormone

nonsteroid hormones tend to be faster than steroid hormones, as they activate enzymes that already exisit within the cell

Hormones participatein negative feedback loops

some hormones → internal homeostatic control mechanisms (negative feedback loop)

negative feedblack loop involving hormone:

- endocrine gland = control center
- hormone = pathway between control center and effectors
- hormone's target cell/tissue/organ = effectors

3. The hypothalamus and the pituitary gland

hypothalamus = small region in the brain → homeostatic control center

- recieves neural input about internal environmental conditions
- produces two hormones of its own
- monitors and controls hormone secretions of the pituitary gland

pituitary gland = consists of an anterior and a posterior lobe, secretes eight different hormones that regulate many of the other endocrine glands

The posterior pituitary stores ADH and oxytocin

neuroendocrine cells = cells in the hypothalamus which function as both nerve cells and endocrine cells → generate nerve impulses + secrete hormones into blood vessels

- cell bodies in the hypothalamus
    - make either antidiuretic hormone (ADH) or oxytocin
    - transport the hormones down the axon for stoarge in axon endings in the posterior pituitary

hypothalamus is stimulated to release the hormones → neuroendocrine cells send impulses down the axon → hormone is secreted into nearby capillaries

antidiuretic hormone (ADH): regulates water balance by causeing changes in cell permeability to water in the kidneys

oxytocin: causes uterine contracts and milk ejection

neuroendocrine reflex → nervous system stimulus responsible for secretion of a hormone

The anterior pititary produces six key hormones

anterior lobe of the pituitary gland produces the following six key anterior pituitary hormones:

- adrenocorticotropic hormone (ACTH), aka corticotropin
  - stimulates the adrenal cortex to release glucocorticoids (involved in stress-related conditions + control of glucose metabolism)
- thyroid-stimulating hormone (TSH), aka thyrotropin
  - stimulates the thryoid gland to synthesize and release thyroid hormones
- follice-stimulating hormone (FSH)
  - in females, FSH induces egg development
  - in males, FSH induces sperm development
- luteinizing hormone (LH)
  - in females, LH promotes ovulation
  - in males, LH stimulates the production of testosterone

FSH + LH: gonadotropins, stimulate growth, development, and function of reproductive organs

Both stimulate secretion of estrogen in females.

- prolactin (PRL)
  - stimulates develoment of mammary glands cells + production of milk
- growth hormone (GH)
  - influences cells in ways that promote growth

each hormone:

- produced and secreted by seperate cell types
- regulated by seperate mechanisms

connection between hypothalamus and anterior pituitary ⇔ neuroendocrine cells in the hypothalamus secrete releasing and inhibiting hormones, which alter the secretion of the six anterior pituitary hormones

Pituitary disorders: Hypersecretion or hyposecretion

many diseases + chronic diseases result of too much hormone (hypersecretion) or too little hormone (hyposecretion)

diabetes insipedes = a disorder where hyposecretion of ADH (posterior pituitary hormone) causes the kidnyes to lose too much water

symptoms include

- excessive urination
- dehydration thirst
- headche
- dry mouth

pituitary dwarfism = the result of hyposecretion of growth hormone during childhood

gigantism = the result of hypersecretion of growth hormone during childhood and adolescence

acromegaly = a condition that comes from excessive production of growth hormone in adults over long periods of time → causes gradual thickining of the bones in the face, hands, and feet

4. The pancreas secretes glucagon, insulin and somatostatin

pancreas = both an endocrine gland and an exocrine gland

endocrine cells of the pancreas are located in small clusters throughout the pancreas → pancreatic islets

these contain three types of cells + produce three hormones → regulation of blood sugar (glucose)

1. alpha cells secrete **glucagon**, raises blood sugar
2. beta cells secrete **insulin**, lowers blood sugar
3. delta cells secrete somatostatin, which appears to inhibit the secretion of both glucagon and insulin

adjusting the blood sugar → altering the relative secretion rates of these two hormones

when blood sugar is high: more insulin, less glucagon

when blood sugar is low: less insulin, more glucagon

5. The adrenal glands comprise the cortex and medulla

adrenal glands = two small endocrine organs located just above te kidneys

each gland: an outer layer (**adrenal cortex**) + inner core (adrenal medulla)

The adrenal cortex: Glucocorticoids and mineralocorticoids

adrenal cortex produces:

- small amounts of estrogen, testosterone
- glucocorticoids (a steroid hormone)
    - help regulate blood glucose levels
- mineralocorticoids (another steroid hormone)
    - help regulate the minerals sodium and potassium

cortisol:

- accounts for 95% of the glucocorticoids produced by the adrenal cortex
- assists in mainitaing blood glucose levels
    - promotes utilization of fats
    - increases breakdown of protein to amino acids in muscle
- important in suppressing inflammatory responses that occur following infection or injury

cortisol secretion → controlled by feedback loop:

- releasing factors from hypothalamus stimulate secretion of ACTH from the anterior pituitary gland
- anterior pituitary gland stimulates the adrenal cortex to secrete cortisol
- when cortisol reaches upper limit of normal blood level → inhibits further secretion of the releasing hormone and of ACTH

aldosterone = the most abundant of the mineralocorticoids → primarily responsible for regulating amounts of sodium + potassium in the body, helps maintain water balance

The adrenal medulla: Epinephrine and norepinephrine

adrenal medulla = inner core of adrenal glands, produces the nonsteroid hormones **epinephrine** (adrenaline) and **norepinephrine** (noradrenaline) → play roles in metabolism and controlling blood pressure/heart activity

though both hormones are also neurotransmitters, they function as hormones when they are released into the blood and act on target cells

once released, these hormones:

- raise blood glucose levels
- increase heart rate and force of contraction
- increase repiration rate
- constrict/dilate blood vessels in many organs

} prepare the body for emergency acitivity

("adrenal rush")

6. Thyroid and parathyroid glands

thyroid gland = a gland situated just below the larynx at the front of the trachea, has two lobes that wrap partially around the trachea

- controls metabolism
- regulates calcium balance
- produces thyroxine and calcitonin

parathryoid glands = four small glands embedded in the back of the thyroid

- regulates calcium balance along with the thyroid
- produce parathyroid hormone

The thyroid gland: Thyroxine speeds cellular metabolism

thyroxine (and triiodothyronine) → hormone(s) produced by the thyroid gland

- acts like a steroid hormone
- increases production and use of ATP from glucose in nearly all body cells
- thryoxine concentration increases ⇔ BMR increases
- blood concentration of thyroxine decreases ⇔ BMR and energy utilization decreases
- basal rate of thyroxine secretion regulated by negative feedback loop

production of active thyroid hormones requires iodine → enlarged thyroid/goiter = result of iodine deficiency

calcitonin = other main hormone of the thryoid gland → decreases the rate of bone resporption by inhibiting the activity of osteoclasts + stimulating uptake of calcium by bone (increases bone mass over time)

Parathyroid hormone (PTH) controls blood calcium levels

parathyroid hormone (PTH) = the only hormone produces by the parathryoid glands

- removes calcium + phosphate from bone
- increases absorption of calcium by digestive tract
- causes the kidneys to retain calcium and excrete phosphate

} raise blood calcium concentration

secretion of PTH = stimulated by low blood calcium levels,
inhibited by high blood calcium levels → an increase in PTH concentration increases the renal activation of vitamin D, which in turn enhances calcium absorption form the digestive tract

7. Testes and ovaries produce sex hormones

human gonads = testes of males, ovaries of females → responsible for production of sperm and eggs, respectively

both also endocrine glands → produce steroid sex hormones

Testes produce testosterone

testes (located in scrotum) produce anrdogens (male sex hormone)

primary androgen: testosterone

- regulates development and normal function of
  - sperm
  - male reproductive organs
  - male sex drive
- responsible for
  - spurt of bone and muscle growth at puberty
  - development of male secondary sex characteristics
    - body hair
    - deepening voice

the adrenal glands in both sexes produce a small amount of a testosterone-likeandrogen → dihydroepiandrosteroene (DHEA)

- has no demonstrable effect on males
- in females, is responsible for many of the same actions as testosterone in males
  - enahncement of female pubertal growth
  - development of axillary (armpit) and pubic hair
  - devleopment and maintence of the female sex drive

Ovaries produce estrogen and progesterone

ovaries (located in the abdomen) produce the female sex hormones → estrogens + progesterone

estrogen:

- initiates development of female sceondary sex characteristics
  - breast development
  - widening pelvis
  - distribution of body fat

both estrogen and progeserone regulate the menstrual cycle

8. Other glands and organs also secrete hormones

Thymus gland hormones aid the immune system

thymus gland = gland located between the lungs, behind the breastbone and near the heart

→ secretes peptide hormones called thymosin and thymopoietin, help lymphocytes develop into mature T cells

The pineal gland secretes melatonin

pineal gland = a pea-sized gland located deep within the brain, in the roof of the third ventricle → secretes the hormone **melatonin** (the "hormone of darkness")

melatonin:

- secreted 10 times faster at night than during the day
- secretion appears to be regulated by absence/presence of visual cues
- important in synchronizing the body's rhytms to the daily light/dark cycle

Endocrine functions of the heart, the digestive system, and the kidneys

the heart, the digestive system, and the kidneys all secrete at least one hormone:

- atrial natruiretic hormone (ANH)
  - peptide secreted by the atria of the heart
  - helps regulate blood pressure
- gastrin, secretin, cholecystokinin
  - hormones secreted by the digestive system
  - have effects on the stomach, pancreas, gallbladder
- erythropoietin, renin
  - secreted by the kidneys
  - erythropoietin stimulates production of red blood cells in bone marrow

9. Other chemical messengers

10. Disorders of the endocrine system

Diabetes mellitus: Inadeqate control of blood sugar

diabetes mellitus = a disease of sugar regulation → common feature: an inability to get glucose into cells where it can be used

symptoms:

- dehydration & thirst
- fatigue
- frequent infections]
- blurred vision
- slow-healing cuts
- tingling in hands/feet

type 1 diabetes (5-10% of all cases) is caused by the failure of the pancrease to produce enough insulin

type 2 diabetes (90-95% of all cases) is insulin resistant → cells fail to respond adequately to insulin even when it is present

Hypothyroidism: Underactive thyroid gland

hypothyroidism = underactivity of the thyroid gland (hyposecretion of thryoid hormones)

in children, insufficient thyroxine production can:

- slow body growth
- alter brain development
- delay the onset of puberty

in adults, insufficient thyroxine can lead to:

- myxedema (edema under the skin)
- lethargy
- weight gain
- low BMR
- low body temperature

Hyperthyroidism: Overactive thyroid gland

hyperthyroidism = overactive thryoid gland causes hypersecretion of thryoid hormones

- increases BMR
- causes:
  - hyperactivity
  - nervousness/agitation
  - weight loss

Addison's disease: Too little cortisol and aldosterone

addison's disease → caused by failure of the adrenal cortex to secrete sufficient cortisol and aldosterone

chronic symptoms of:

- fatigue
- weakness
- abdominal pain
- weight loss
- characteristic "bronzed" skin color

Cushing's synrdome: Too much cortisol

cushing's syndrome = due to exaggerated effects of too much cortisol → excessive production of glucose cause retention of too much salt and water, causing blood glucose concentration to rise and muscle mass to decrease

symptoms:

- muscle weakness
- fatique
- edema
- high blood pressure

The digestive system and nutrition

- Nutrients: substances in food that are required for growth, reproduction and the maintenance of health.

1. The digestive system brings nutrients into the body

- The digestive system consists of the gastronomical (GI) tract and four accessory organs: the salivary glands, liver, gallbladder, and pancreas
- The five basic processes of the digestive system are mobility, secretion, digestion, absorption, and excretion
- Two types of motility in the GI tract are peristalsis, which propels foods forward, and segmentation, which mixes the contents

- Digestive system: consists of all the organs that share the common function of getting nutrients to the body.
- Gastrointestinal tract (GT): organs from a hollow tube
- Lumen: the space within this hollow tube, the area through which food and liquids travel
- FIG 14.1 !!

these walls of the GI tract are composed of four layers

- Mucosa: the innermost layer. All nutrients must cross the mucosa to enter the blood.
- Submucosa: a layer of connective tissue containing blood vessels, lymph vessels and nerves. Components of food that are absorbed across the mucosa enter the blood and lymph vessels of the submucosa.
- Muscularis: is responsible for motility or movement. Consists out of 2 or 3 sublayers of smooth muscle.
- Serosa: thin connective tissue sheath that surrounds and protects the other three layers and attaches the digestive system to the walls of the body cavities.

Recap: The digestive system consists of organs and accessory organs that share the function of bringing nutrients into the body. The wall of the GI tract consists of four tissues layers: the mucosa, the submucosa, the muscularis, and the serosa.

Five basic processes accomplish digestive system function

- Mechanical processing and movement: chewing breaks food into smaller pieces, and 2 types of movement mix the contents of the lumen and propel it forward.
- Secretion: fluid, digestive enzymes, acid, alkali, bile and mucus are all secreted into the GI tract at various places. In addition, several hormones that regulate digestion are secreted into the bloodstream.
- Digestion: the contents of the lumen are broken down both mechanically and chemically into smaller and smaller particles, culminating in nutrient molecules.
- Absorption: nutrient molecules pass across the mucosal layer of the GI tract into the blood or lymph
- Elimination: undigested material is eliminated from the body via the anus.

Two types of motility aid digestive processes

- Peristalsis: propels food forward.
  - Begins when a lump of food stretches a portion of the GI tract, causing the smooth muscle in front of the bolus to relax and the muscle begin it to contract.
- Segmentation: mixes food
  - In segmentation short sections of smooth muscle contract and relax in seemingly random fashion.

2. The mouth processes food for swallowing

- The 32 teeth of adults include incisors, canines, premolars, and molars. Teeth cut, tear grind, and crush food.
- Saliva moistens food, begins the digestion of starch, and helps to protect against bacteria.

Teeth bite and chew food

- The teeth chew food into pieces small enough to swallow.
- 4 types of teeth:
  - Sharp-edged incisors: cut the food
  - Pointed canines: tear it
  - Pre-molars and molars: grinding and crushing the food.
- Children 20 teeth, adults 32

- Crown: is covered by a layer of enamel
- Enamel an extremely hard nonliving compound of calcium and phosphate.
- Beneath the enamel is a bonelike living layer called dentin
- The soft innermost pulp cavity contains the blood vessels that supply the dentin as well as the nerves

- Our mouth contain a large number of bacteria that flourish on the food that remains between the teeth. During metabolism these bacteria release acids that can dissolve enamel, creating cavities or dental caries.
  - Tooth decay may inflame the soft gum tissue around the tooth → gingivitis
  - Decay can inflame the periodontal membrane →periondontities.

The tongue positions and tastes food

- The tongue consists of skeletal muscle enclosed in mucus membrane, so we have voluntary control over its movements.
- Contributes to the sense of taste and also is important for speech.

Saliva begins the process of digestion

- Three pair of salivary glands produce a watery fluid called, saliva.
- Saliva moistens food, making it easier to chew and swallow.
- Four main ingredients:
  - Mucin : a mucus-like protein that holds food particles together and so they can be swallowed more easily
  - Salivary amylase: begins the process of digesting carbohydrates.
  - Bicarbonate: the range over which salivary amylase is most effective (ph between 6.5 and 7.5)
  - Lysozyme: inhibits bacterial growth

Recap: The four kinds of teeth (molars, premolars, canines, and incisors) mechanically digest chunks of food. Salivary glands secrete saliva, which moistens food, begins the chemical digestion of carbohydrates, maintains the PH of the mouth, and protects the teeth against bacteria.

3. The pharynx and esophagus deliver food to the stomach

- Pharynx or throat
- Swallowing:
  - Voluntary movements of the tongue and jaws push a bolus of food into the pharynx
  - The presence of food stimulates receptors in the pharynx and initiates…
  - A second involuntary phase, the 'swallowing reflex'

- Just beyond the pharynx is the esophagus, a muscular tube consisting of both skeletal and smooth muscle that connects the pharynx to the stomach.
  - Esophagus: produces lubricating mucus that helps food slide easily.

- Occasionally the sphincter malfunctions, → acid reflux. Backflow of acidic stomach fluid into the esophagus.
  - Acid reflux becomes more common with weight gain, pregnancy and age
  - Occasionally it indicates a hiatal hernia, a condition in which part of the stomach protrudes upward into the chest through an opening in the diaphragm muscle.

- Swallowing is a reflex that is initiated by voluntary movements of the tongue. Once started, swallowing is voluntary.
- The sole function of the esophagus is to get food from the mouth to the stomach
- The lower esophageal sphincter prevents reflux of stomach contents.

Recap: swallowing begins with voluntary movements of the tongue; the presence of food initiates an involuntary swallowing reflex. Peristalsis and gravity transfer food trough the esophagus to the stomach.

4. The stomach stores food, digests protein and regulates delivery

- Food storage: stores the food until it can be digested and absorbed.
- Digestion
- Regulation of delivery: regulates the rate at which food is delivered to the small intestine.

- The stomach stores ingested food until it can be delivered to the small intestine.
- Glands in the mucosa of the stomach secrete gastric juice into the lumen, beginning the process of protein digestion
- Peristalsis of the stomach mixes the food and pushes it toward the small intestine

Gastric juice breaks down proteins

- Maagsap
  - Kleine openingen naar maagklieren
    - Secretie HCl
    - Secretie slijm (maagwand beschermen tegen zure inhoud)
    - Secretie pepsinogen (enzyme pepsin in zure omgeving)
  - pH = 2
  - 1-2 liter per dag
  - Proteïnen & peptiden afgebroken tot aminzuren
  - Spijsbrij = deels verteerd voedsel & maagsappen → naar dunne darm: geregeld door pylorische sluitspier

Recap: the stomach stores food, digests it, and regulates its delivery to the small intestine. Gastric juice dissolve connective tissue, large proteins, and peptides in food.

Stomach contractions mix food and push it forward

- Maagcontracties: peristalsis
  - Start aan onderste sluitspier van slokdarm → pylorische sluitspier
  - Elke 15-25 seconden
  - Elke contractie: eetlepel spijsbrij in dunne darm
  - 2-6 uur eer maag leeg is
  - Zuur spijsbrij → secretie hormonen → vertragen peristalsis → dunne darm voedingsstoffen absorberen

Recap: the presence of food stretches the stomach and increases peristalsis. Peristaltic contractions mix the chyme and push it gradually in the small intestine.

5. The small intestine digests food and absorbs nutrients and water

- Digestion occurs primarily in the first part of the small intestine, called the duodenum
- The jejunum and ileum of the small intestine absorbs most of the products of digestion
- The smallest intestine has a very large surface area because of its many folds, villi, and microvilli

- Digestion: digest proteins to smaller peptides under influence of strong acids and pepsin.
- Absorption
- The small intestine consist of three different regions.
  - Duodenum: here most of the digestion takes place.
  - Jejunum and ileum: the products of digestion are absorbed here.

Recap: The small intestine has two major functions: a. digesting proteins, carbohydrates and lipids; and b. absorbing approximately 90% of the nutrients and water we consume. Projections called villi in the mucosa increase the small intestine's surface area for absorption.

6. Accessory organs aid digestion and absorption

- The pancreas secretes fluid containing bicarbonate and digestive enzymes into the small intestine
- The liver produces bile and participates in homeostasis in a variety of ways
- All of the venous blood from the GI tract is routed directly to the liver
- The gallbladder stores bile from the liver and concentrates it by removal of most of the water

The pancreas secretes enzymes and NaHCO3

- The pancreas an elongated organ that lies just behind the stomach, had both endocrine and exocrine functions
    - Pancreas produces and secretes
        - Digestive enzymes:
        - Sodium bicarbonate → neutralize stomach acid.
- Fig 14.14
-
- *Recap: The pancreas assists digestion by producing (1) digestive enzymes and (2) sodium bicarbonate to neutralize stomach acid and make enzymes more effective*

The liver produces bile and performs many other functions

Recap: Bile is produced by the liver and stored in the gallbladder until after a meal. The liver also produced plasma proteins; inactivates toxic chemicals; destroys old red blood cells; stores vitamins, iron and certain products of metabolism; and performs other functions important for homeostasis.

7. The large intestine absorbs nutrients and eliminates wastes

- The large intestine absorbs most of the remaining nutrients and water and stores the now nearly solid waste material until it can be eliminated.

- A small fingerlike pouch, the appendix extends from the cecum. → no known digestive function BUT we become acutely aware of its presence if it becomes inflamed of infected. = appendicitis

- Most of the intestine consists of four regions collectively called the colon
    - Ascending colon: rises along the right side of the body
    - Transverse colon: crosses over to the left side
    - Descending colon: passes down the left side to the shirt final segment
    - The sigmoid colon: feces are stored in the sigmoid colon until defection, when they pass through the rectum to the anus.

- Defecation is controlled by a neural reflex. Normally the anus is kept closed by contraction of a ring of smooth muscle: internal anal sphincter
- We can prevent defection by voluntarily contracting the external anal sphincter, a ring of skeletal muscle under our conscious control.

> - The large intestine absorbs most remaining nutrients and water, and vitamin H produced by bacteria. It also stored wastes
> - Defecation is generally controlled by a neural reflex, but it can be overridden by conscious control

> *Recap: The large intestine absorbs the last of the water, ions, and some nutrients and stores feces until defecation occurs*

8. How nutrients are absorbed

> - Amino acids and simple sugars are actively transported into the mucosal cells that line the small and large intestines
> - The products of fat digestion enter the mucosal cells by diffusion, then re-form into triglycerides. Triglycerides are coated with protein and move into lymph vessels for transport to the blood
> - Water is absorbed by osmosis
> - Vitamins and minerals follow a variety of specific pathways

Proteins and carbohydrates are absorbed by active transport

- Digestion and absorption of proteins and carbohydrates in the small intestine:
  - Digestion depends on enzymes from the pancreas and enzymes attached to the surface of the epithelial cells of the intestine. The amino acid and carbohydrate products of digestion cross the epithelial cell layer of the mucosa and enter a capillary for transport to the liver

Recap: Proteins and carbohydrates are absorbed from the lumen of the small intestine by active transport processes, then move by facilitated diffusion into capillaries.

Lipids are broken down and then reassembledµ

- Because they are nonplar the fatty acids and monoglycerides quickly dissolve in micelles(small droplets composed of bile salts and lecithin that have a polar outer surface and non polar inner core)
  - Function of micelles: transport fatty acids and monoglycerides to the outer surface of the mucosal cells so that they can be absorbed into the cells.

Water is absorbed by osmosis

- As nutrients are absorbed in the small intestine, the concentration of the water in the intestinal lumen becomes higher than in the intestinal cells or in the blood.

Vitamins and minerals follow a variety of paths

- Fat-soluble vitamins dissolve in the micelles and are absorbed by diffusion across the lipid membrane of the mucosal cell layer, just like the components of lipids. Water –soluble vitamins are absorbed either by active transport or diffusion through channels or pores

Recap: The components of lipid digestion are transported to the mucosa in micelles, diffuse into the cell, and recombine into lipids within the cell. Then they are coated with protein to become chylomicrons that enter the lymph. The digestive system also absorbs water, vitamins, minerals, and digestive secretion.

9. Endocrine and nervous systems regulate digestion

- The volume and content of food play a large part in regulating digestive processes
- Stretching of the stomach increases stomach peristalsis and the secretion of gastric juice
- Stretching of the small intestine inhibits gastric motility, increases intestinal segmentation, and cases the secretion of two digestive enzymes, secretin and cholecysokinin
- Acid in the small intestine triggers the secretion of pancreatic juice containing bicarbonate

Regulation depends on volume and content of food

- Gastrin: is a hormone released when stretching and the presence of protein stimulates the stomach, triggers the release of more gastric juice.
- Secretin: stimulates the pancreas to secrete water and bicarbonate to neutralize acid.
- Cholecystokinin (CCK): stimulate by fat and protein. Signals the pancreas to secrete more digestive enzymes. CCK and stretching of the duodenum also sitmulate the gallbladder to contract and release bile.

Organ	Nervous system	Endocrine system
stomach	Stretching increases peristalsis and secretion of gastric juice	Stretching and protein trigger release of gastrin, which stimulates gastric glands
Small intestine	Stretching increases segmentation Stretching inhibits stomach motility and stomach secretions	Acid stimulates release of secretin, which stimulates pancreas to secrete bicarbonate, neutralizing acid. Fat and protein stimulate relase of cholecystokinin (CCK) , which stimulates the pancreas to secrete enzymes and the gallbladder to release bile. CCK and secretin inhibit stomach motility and stomach secretions.
Large intestine	Stomach stretching increases motility	Gastrin increases motility.

Recap: The endocrine and nervous systems regulate digestion based on content and volume of food. Regulatory mechanisms include neural reflexes involving organ stretching and release of the hormones gastrin, secretin, and cholecystokinin.

Nutrients are used or stored until needed

- Fig 14.15

Recap: lipids, carbohydrates, and amino acids can all be converted to storage forms of lipid or carbohydrates. They can be recreated from stored forms according to the body's needs at the moment

10. Nutrition: you are what you eat

- Good nutrition requires a variety of foods weighted toward fruits, vegetables, and whole-grains products
- The human body needs certain nutritional components that it cannot make, including a few fatty acids, eight amino acids, 13 vitamins and all essential minerals

Mypyramid plan offers a personalized approach

Recap: Good nutrition includes maintaining a healthy weight while consuming a variety of foods. Eat plenty of fruit, vegetables, and whole grains; cut back on saturated fat; and use sugar salt and alcohol in moderation.

Carbohydrates: a major energy source

- Carbohydrates: are one of the body's main sources of energy.

Recap: carbohydrates are a good source of energy. Natural sugars and complex carbohydrates are the best sources.

Lipids: essential cell components and energy sources

- Lipids: are essential components of every living cell. Phospholipids and cholesterol make up most of the cell membrane
  - Saturated fats
  - Unsaturated fats

Recap: Saturated fats are found mostly in meat and dairy products, and trans fats are found in many snacks and processed foods. Unsaturated fats, which include plant and fish oils, are a healthier choice. Some essential fatty acids must be consumed to meet the body's nutritional requirements.

Complete proteins contain every amino acid

- Proteins are vital components of every cell. They make up the enzymes that direct metabolism, they serve as receptor and transport molecules, and they build our muscle fibers.
- Essential amino acids: they must be ingested in food
- Complete protein: contains all 20 of the amino acids in proportions that meet our nutritional needs.

Recap: The body needs 20 amino acids but cannot synthesize eight of them, called essential amino acids. Complete proteins contain all 20 amino acids. Most animal proteins are complete but most plant proteins are incomplete.

Vitamins are essential for normal function

Minerals: elements essential for body processes

- Minerals are the atoms of certain chemical elements that are also essential for body processes.

Fiber benefits the colon

- Fiber: found in many vegetables, fruit and grains. Is indigestible. is beneficial because it makes feces bulky and helps them pass more efficiently through the colon

Recap: All minerals and nearly all vitamins must be obtained from food. For most healthy people, a balanced diet, including adequate fiber, is the best way to achieve the RDA.

11. Weight control: energy consumed energy spent

- The basal metabolic rate (BMR) represents the daily energy needs of the body for all essential activities except physical activity
- Fat contains over twice as many calories per gram as carbohydrate or protein
- A person must use 3500 calories more than he or she ingests to lose a pound of body fat

BMR: determining how many calories we need

- Basal metabolic rate: the energy your body needs to perform essential activities such as breathing and maintaining organ function.
- Can be influenced by the following factors:
  - Gender and body composition
  - Age
  - Health
  - Stress
  - Food intake
  - Genetics

Energy balance and body weight

- Healthy weight control involves balancing energy intake against energy expenditure.

Recap: weight control involves balancing energy consumed in food against energy spent. Calculating your BMR helps you estimate how many calories you need each day.

Physical activity: an efficient way to use calories

Healthy weight improves overall health

Recap: Increasing physical activity is an efficient way to increase calories expenditure. The best strategy for losing weight combines a healthful diet with moderate regular exercise.

12. Disorders of the digestive system

- Food poisoning: one of the most common conditions worldwide, caused by food and beverages contaminated with bacteria or their toxic products→ diarrhea and vomiting
- Food allergies: → diarrhea, vomiting and generalized allergic responses throughout the body.

> - Lactose intolerance is caused by the lack of the enzyme (lactase) that normally digests lactose
> - Hepatitis, or inflammation of the liver, can be caused by several different viruses
> - Starvation is the most common form of malnutrition in the world. However, the incidence of obesity is rising in the U.S. and other industrialized nations

Disorders of the GI tract

- Lactose intolerance: difficulty digesting milk
  - Symptoms:
    - Diarrhea
    - Gas
    - Bloating
    - Abdominal cramps
- Peptic ulcers: sores in the stomach
  - Peptic ulcers are painful erosions of the mucosal lining of the stomach or duodenum.
- Celiac disease (gluten intolerance)
  - Symptoms:
    - Vary widely
    - Acute abdominal pain
    - Vomiting
    - Chronic fatigue
    - Depression
    - Eventually malnutrition
- Diverticulitis: weakness in the wall of the large intestine
- Colon polyps: noncancerous growths

Disorders of the accessory organs

- Hepatitis: inflammation of the liver
- Caused by viruses or toxic substances

- Hepatitis A
    - Transmitted by contaminated food or water and causes a brief illness from which most people recover completely.
    - Vaccine available
- Hepatitis B
    - Transmitted by blood or body fluids, so it is usually passed via contaminated needles, blood transfusion or sexual contact with infected persons.
    - → liver failure
    - Symptoms: jaundice, nausea, fatigue, abdominal pain and arthritis.
    - Vaccine available
- Hepatitis C
    - Transmitted by infected blood, usually through contaminated needles or blood transfusions.
    - May remain dormant for years but still damage the liver.

- Gallstones can obstruct bile flow
    - Treatments: drugs, ultrasound vibrations, laser treatments, surgery

Malnutrition: too many of too few nutrients

- Malnutrition can be caused either by over nutrition or under nutrition.

Obesity: a worldwide epidemic?

Recap: Disorders of the GI tract and accessory organs include lactose intolerance, diverticulosis, colon polyps, gallstones and hepatitis. Malnutrition can be caused by over- or undernutrition. Whereas starvation is the leading cause of malnutrition in underdeveloped countries, obesity is increasing in industrialized nations.

13. Eating disorders : anorexia nervosa and bulimia

- Anorexia nervosa: is a condition in which a person diets excessively or stops eating altogether, even to the pont of starvation and death
  - Symptoms:
    - Refusal to maintain healthy body weight
    - Intense fear of gaining weight
    - Distorted perception or preoccupation
    - In premenopausal women, the absence of at least three consecutive menstrual cycle.
- Bulimia: is binge and purge condition in which someone eats and deliberately vomits or takes other steps to minimize the calories ingested.
  - Symptoms
    - Recurrent episodes of binge eating
      - Eating large amounts of food
      - Feeling a lack of control over eating
    - Taking recurrent inappropriate steps to prevent weight gain, such as self-induced vomiting.
    - Binge eating and compensatory behaviors that occur
    - Preoccupation with body shape and weight

- Two serious eating disorders are anorexia nervosa, in which the person diets excessively or stops eating entirely, and bulimia, a binge-and-purge condition in which the person eats and deliberately vomits or takes other steps to minimize caloric intake
- The most effective treatments are multidisciplinary, addressing medical, psychiatric, dental, psychological and nutritional needs

The urinary system

1. The urinary system contributes to homeostasis

- Excretion refers to processes that remove wastes and excess materials from the body
- The urinary system consists of the kidneys, the ureters, bladder and uretha.
- The two kidneys produce urine.
- The other components of the urinary system just transport and store urine until it is eliminated from the body.

- The kidneys, the lungs, the liver, and the skin all participate in the maintenance of homeostasis
- The kidneys are the primary regulators of water balance and most excess solutes, especially inorganic ions and urea

The kidneys regulate water levels

The kidneys regulate nitrogenous wasted and other solutes

- The primary solutes excreted by the kidneys are nitrogenous wastes, excess ions, and trace amounts of other substance, as described below.
- Ammonia is toxic to cells but the liver quickly detoxifies it by combining two ammonia molecules with a molecule of carbon dioxide to produce urea.

Recap: the urinary system maintains a constant internal environment by regulating water balance and body levels of nitrogenous wastes, ions, and other substances. It filters metabolic wastes from the blood and excretes them in urine. The major nitrogenous waste product is urea.

2. Organs of the urinary system

- The urinary system consists of those organs that produce, transport, store and excrete urine. The urinary system includes the kidneys, the ureters, the bladder, and the urethra.
- Functions of the kidneys include regulation of the volume and composition of body fluids, excretion of wastes, regulation of blood pressure, regulation of the production of red blood cells, and the activation of vitamin D.

Kidneys: the principal urinary organs

- Functions:
  - Excrete metabolic wastes, especially urea
  - Maintain water and salt homeostasis
  - Help regulate acid-base balance
  - Help regulate blood pressure
  - Control red blood cell production
  - Activate vitamin D
- Medulla: inner pyramid-shaped zones of dense tissue.
- Cortex: outer zone

- Renal pelvis: the center, a hollow zone where urine collects after it is formed.

Ureters transport urine to the bladder

- The renal pelvis of each kidney is continuous with a ureter a muscular tube that transports urine to the bladder.

Urinary bladder stores urine

- The urinary bladder stores urine.
- The bladder consists of three layers of smooth muscle lined on the inside by epithelial cells.
- Women have a smaller bladder than man, because their bladders are slightly compressed by the uterus.

Urethra carries urine from the body

- During urination, urine passes through the urethra, a single muscular tube that extends from the bladder to the body's external opening.

Recap: organs of the urinary systems include the kidneys, ureters, bladder, and urethra. The kidneys are the principal urinary organs, although they have several homeostatic functions as well. The ureters transport urine to the bladder, where it is sorted until carried by the urethra to the body's external opening.

3. Nephrons produce urine

- Each kidney contains a million small functional units called nephrons.
- An individual nephron consists of a thin, hollow tube of epithelial cels, called a tubule + blood vessels that supply the tubule.
    - Function: produce urine.

- The functional unit of the kidneys is the nephron. Each nephron consists of a tubular component and the blood vessels that supply it.
- The tubular components of a nephron are the glomerular capsule, proximal tubule, loop of Henle, distal tubule, and collecting duct. The collecting duct is shared by many nephrons.
- A tuft of capillaries called the glomerulus is enclosed within each glomerular capsule. Peritubular capillaries supply proximal and distal tubules, and vasa recta supply loops of Henle and collecting ducts.

The tubule filters fluid and reabsorbs substances

- The nephron begins with a cup of tissue thath looks like a deflated ball with one side pushedin, the glomerular capsule.
- The glomerular capsule surrounds and encloses a network of capillaries called the glomerus, which is part of the blood supply of the nephron.
- The proximal tube: starts at the glomerular capsule and ends at the renal medulla.
- The hairpin-shaped loop of Henle extends into the medulla as the descending limb and then loops back up to the vicinity of the glomeral capsule.
    - The tube is called the distal tubule.
- Finally the distal tubules of up to a thousand nephrons join to become a collecting duct.

Special blood vessels supply the tubule

- Every nephron is supplied by a single arteriole, the afferent arteriole.
- The glomerular capillaries rejoin to become the efferent arteriole, which carries filtered blood from the glomerulus. The efferent arteriole divides again into another capillary network that surrounds the proximal and distal tubules in the cortex, called the peritubular capillaries.
- The efferent arterioles of a few nephrons descend into the medulla and divide into long, thin capillaries called the vasa recta. That supply the loop of Henle and collection duct.

Recap: A nephron is the functional unit of a kidney. A nephron tubule consists of a glomerular capsule, where fluid is filtered, and four regions in which the filtrate is modified before it becomes urine: proximal tubule, loop of Henle, distal tubule, and collecting duct. Blood flows to the glomerulus via the renal artery and afferent arterioles. Peritubular capillaries carry the blood to the proximal and distal tubules, and vasa recta supply the loops of Henle and collecting ducts.

4. Formation of urine: filtration, reabsorbtion and secretion

- The formation of urine involves three processes: glomerular filtration, tubular reabsorption, and tubular secretion.
- Approximately 180 liters per day of protein-free plasma fluid is filtered across the glomerulus and into the glomerular space. Filtration is driven by high blood in the glomerular capillaries.
- Ninety-nine percent of all filtered water and salt and all of the filtered bicarbonate, glucose, and amino acdis and reabsorbed in tubular reabsorption. The active transport of sodium provides the driving force of the reabsorption of nearly all other substances.
- Tubular secretion is a minor process relative to reabsorption but is critical for the regulation of acid-base balance and for the removal of certain toxic wastes.

Glomerular filtration filters fluid form capillaries

- Glomerular filtration: the process of filtering a large quantity og protein-free plasma fluid from the glomerular capillaries into the glomerular space.

Recap: glomerular filtration separates plasma fluid and small solutes from larger proteins and blood cells. High blood pressure in the glomerular capillaries drives this process.

Tubular reabsorption returns filtered water and solutes to blood

- Tubular reabsorption: the second step in urine formation. Returns filtered water and solutes from the tubule into the blood of the peritubular capillaries or vasa recta.
- Basic mechanisms of reabsorption in the proximal tubule
  - The key to the entire process is the active transport of sodium across the tubular cell membrane on the capillary side of the cell.
  - This step requires energy in the form of ATP.
  - The active transport of sodium keeps the intracellular sodium concentration low, which permits sodium to enter into the cell from the luminal side by facilitated transport.
  - Negatively charged chloride ions follow in order to maintain electrical neutrality, and water follow because the reabsorption of sodium and chloride produces an osmotic driving force for the diffusion of water.

  - Finally, the facilitated transport of sodium across the luminal membrane is used as an energy source for the reabsorption of glucose and amino acids.

Tubular secretion removes other substances from blood

- Tubular secretion : they move from the capillaries into the tubule to excreted. Tubular secretion may occur by either active transport or passive diffusion, depending on the substance being secreted.

Recap: during tubular reabsorption, nearly all the filtered water and sodium and all the major nutrients are reabsorbed from the nephron tubule. The process begins with the active transport of sodium across the cell membrane located on the capillary side of the tubular cell. Tubular secretion removes toxic, foreign, and excess substances from the capillaries. It is essential to the regulation of acid-base balance, potassium balance, and the excretion of certain wastes.

5. The kidneys can produce dilute or concentrate urine

- The ability of the kidneys to form either dilute or concentrated urine depends on the high solute concentration in the renal medulla and the ability to alter the permeability of the collecting duct to water.
- Dilute urine is formed in the absence of the hormone ADH. In the absence of ADH, reabsorption of salt without reabsorption of water continues in the collecting duct.
- Concentrated urine is formed when ADH increases the collecting duct's permeability to water, allowing water to diffuse toward the high solute concentration in the medulla.
- The ability of the kidneys to produce concentrated urine is dependent upon a countercurrent mechanism that exists in the hairpin arrangements of the loops of Henle and the vasa recta.

Producing dilute urine: excreting excess water

- The formation of a high volume of dilute urine
  - Urine volume is regulated by controlling the water permeability of the collecting duct.
  - In the absence of antidiurectic hormone (ADH) the distal tubule is impermeable to water
  - The tubular fluid had been diluted by the active reabsorption of salt, and this fluid passes through the medulla in the collecting duct without being reabsorbed.

Recap: production of dilute urine requires the reabsorption of salt without the concurrent reabsorption of water in the ascending limb of the loop of Henle, the distal tubule, and the collecting duct

Producing concentrated urine: conserving water

- The process of reabsorbing water is regulated by antidiurectic hormone (ADH) form the posterior pituitary gland.
- The formation of a low volume of concentrated urine.
  - In the presence of the ADH the collecting duct becomes permeable to water.
  - Most of the water in the collecting duct is reabsorbed by passive diffusion as the fluid passes through the medulla with its high solute concentration.
- Countercurrent exchange in the vasa recta.
  - Remove water and solutes that accumulate in the medulla as a result of reabsorption from the loop of Henle and the collecting duct.
  - The vasa recta are highly permeable to water and solutes and rapidly equilibrate with their surrounding fluid.
  - The countercurrent flow of blood in the two parallel vessels of the vasa recta permits the rapid exchange of water and solutes by diffusion, at the same time preserving the medullary concentration gradient from top to bottom.

Recap: the formation of concentrated urine requires antidiuretic hormone (ADH). In the presence of ADH, most of the water is reabsorbed from the collecting duct, leaving a small volume of concentrated urine to be excreted

6. Urination depends on a reflex

- Urination is caused by the micturition reflex, a neural reflex initiated when the bladder is stretched.
- Urination can be prevented by higher (voluntary) neural signals from the brain.

Recap: Urination depends on the neural micturition reflex; bladder stretching initiates involuntary relaxation of the internal urethral sphincter. The brain can override the reflex by voluntary contraction of the external urethral sphincter.

7. The kidneys maintain homeostasis in many ways

- Contributes to the maintenance of water balance
- Contributes to the maintenance of salt balance
- Secrete an enzyme involved the control of blood volume and blood pressure
- Maintain acid-base balance and blood pH

- water balance is maintained by a negative feedback loop involving ADH. Te main stimulus for the secretion of ADH is an increase in the solute concentration of the blood.
- Blood volume is regulated by maintenance of the body's salt balance, which is controlled primarily by a negative feedback loop influenced by two hormones: renin from the kidney and aldosterone from the adrenal cortex
- The kidneys secrete (and excrete) $H+$ and $NH4+$ in amounts equal to the net gain of acid per day (other than as $CO2$). They also secrete $H+$ as part of the mechanism for the absorption of all filtered $HCO3-$
- The kidneys synthesize and secrete erythropoietin, the hormone responsible for the regulation of red blood cell production.
- The kidneys are required for the activation of vitamin D.

ADH regulates water balance

- Negative feedback loop for the control of blood solute concentration
  - A rise in blood solute concentration tiggers thirst and increases ADH secretion.
  - ADH causes the kidneys to form a more concentrated urine and decrease their excreation of water.
  - An increase in water intake coupled with a reduction in water loss from the kidneys dilutes the blood and returns blood solute concentration toward normal.

Aldosterone regulates salt balance

- The control of blood volume depens critically on maintaining the body's salt balance.
- Sodium secretion by the kidneys is regulated by aldosterone, a steroid hormone from the adrenal gland.

The rennin-angiotensin system controls blood volume and blood pressure.

- Renin- angiotensin system does not fit the classical definition of a hormone, for there is no one gland that releases a hormone into the blood.
- The controlling component of the renin-angiotensin system is an enzyme called renin.
  - Renin is synthesized and stored in specialized cells of the afferent arteriole in a region near the glomerulus called the juxtaglomerular apparatus.

Atrial natriuretic hormone protects against blood volume excess

- There is another controller of renal sodium excretion unrelated to aldosterone: a peptide hormone called atrial natriuretic hormone.

Recap: The solute concentration of blood is maintained by a feedback loop involving ADH. Renal excretion of sodium is regulated largely by aldosterone, which in turn is controlled by the secretion of renin in response to changes in blood volume of blood pressure. The hormone AHN stimulates sodium excretion.

Kidneys help maintain acid-base balance and blood pH

- The kidneys participate in the maintenance of acid-base balance, a role they share with various buffers in the body and with the lungs
  - Reabsorption of filtered bicarbonate
  - Renal excretion of acid as ammonium

Erythropoietin stimulates production of red blood cells

- The kidneys regulate the production of red blood cells in the bone marrow. They do this by secreting a hormone, erythropoietin.

Kidneys activate vitamin D

- Vitamin D is important for absorbing calcium and phosphate from the digestive tract and developing healthy bones and teeth.
- Vitamin D synthesis begins when ultraviolet rays in sunlight strike a steroid molecule in skin that is similar to cholesterol, producing an inactive form of vitamin D.
- The inactive form is transported to the liver, where it is chemically altered, then carried to the kidneys, where it is converted to its active form under the influence of parathyroid hormone from the parathyroid gland.

Recap: The kidneys help maintain the body's acid-base and blood PH by reabsorbing all filtered bicarbonate and by excreting H+. decreased oxygen delivery to the kidneys triggers the release of erythropoietin, which stimulates the production of red blood cells by bone marrow. Synthesis of vitamin D involves the skin, liver, and kidneys.

8. Disorders of the urinary system

- The kidneys are vulnerable to damage by toxic substances, infections, sustained decreases in blood pressure, or blockage of urination outflow.
- Nephrons that are damaged berond repair are not replaced
- Hemodailysis is an artificial procedure for cleansing the blood of wastes and excess solutes.
- Renal transplantation is technically easy and usually quite successful, but there is a shortage of donor kidneys.

Kidneys stones can block urine flow

- Sometimes minerals in urine crystallize in the renal pelvis and form solid masses called kidney stones.

Urinary tract infections are often caused by bacteria

- A urinary tract infection refers to the presence of microns in urine or a infection in any part of the urinary system.
- Most UTI's are causes by bacteria that make their way up to the urethra from the body surface.

Acute and chronic renal failure repair kidney function

- Kidney impairments that are short term and possibly correctable are called acute renal failure
- Chronic renal failure also known as end-stage renal disease is defined as long-term irreversible damage leading to at least 60 % reduction in functioning nephrons and failure of the kidneys to function properly.

Recap: the kidneys have a huge reserve of function. However, acute or chronic renal failure can result from prolonged changes in blood pressure, disease, large kidney stones, transfusion reactions, burns, injuries, toxic substances, and other conditions such as diabetes.

Dialysis cleanses the blood artificially

- Dialysis: attempts to duplicate the functions of healthy kidneys.
- A dialysis technique that can be done at home without a kidney machine is called continuous ambulatory peritoneal dialysis.
- Another type called hemodialysis, the patient's blood is circulated through an artificial kidney machine consisting of semi permeable membranes in contact with a large volume of clean fluid.

Kidney transplants are a permanent solution to renal failure.

Recap: CAPD is an at-home dialysis technique in which fluid is placed in the peritoneal cavity and replaced at regular intervals. Hemodialysis cleanses the blood by means of an artificial kidney machine consisting of a semipermeable membrane and clean fluid. Kidney transplants are the best hope for people in renal failure. Currently there is a severe shortage of kidneys available for transplant.

Reproductive systems

- The reproductive system: sexual attractiveness and sexual arousal are normal events in the human reproductive process.

1. The male reproduction system delivers sperm

- Sperm: the male reproductive system evolved to deliver the male reproductive cells**.**
  - Sperm are produced in the male reproductive organs, called the testes, and stored in the epididymis and ductus deferens.
  - Semen contains perm and the secretion of three glands: the seminal vesicles, the prostate gland and the bulbourethral glands.
  - Tens of millions of sperm are formed every throughout the male's adult life. The production of sperm is under the control of three hormones: testosterone, LH and FSH.

Testes produce sperm

- Testes: the sites of sperm production in the male
  - Shortly before birth the testes descend in to the scrotum.
    - Scrotum: regulates the temperature of the developing sperm within the testes. (best temp. is a few degrees cooler than body temp.)
  - Each testis contains a packed seminiferous tubules, where sperm are produced. The seminiferous tubules join to become the epididymis.
  - The epididymis: a single coiled duct just outside the testis. The epidiymis joins the long ductus (vas) deferens, which eventually joins the duct from the seminal vesicle to become the ejaculatory duct

- The penis: is the male organ of sexual intercourse. Its function is to deliver sperm internally to the female, safely away from the harsh external environment.
    - Contains erectile tissues that permits erection.

Accessory glands help sperm survive

- Semen: to improve their chances of survival, the male delivers sperm in a thick, whitish mixture of fluids.
- The seminal vesicles: produce seminal fluid, a watery mixture containing fructose and prostaglandins that represents about 60 % of the volume of semen
- The prostate gland: contributes an alkaline fluid.
- The bulbourethral glands: secrete mucus into the uretha during the sexual arousal. The mucus washes away traces of acidic urine in the urethra before the sperm arrive and also provides lubrication for sexual intercourse.

Organ	Function
Testis	Produces sperm, testosterone and inhibin
Scrotum	Keeps the testes ate the proper temperature
Epididymis	Site of sperm maturation and storage
Ductus deferes	Duct for sperm maturation storage and transport
Ejaculatory duct	Duct for transporting sperm and glandular secretions
Penis	Erectile organ of sexual intercourse.

Accessory glands	
Seminal vesicle	Secretes fructose and most of the seminal fluid
Prostate gland	Secretes watery alkaline fluid to raise vaginal PH
Bulbourethal gland	Secretes lubricating mucus.

Recap: the male reproductive system consists of the testes where sperm are produced, a series of duct and accessory glands, and the penis. Semen consists of sperm and three glandular secretions that provide energy and the proper PH environment for the sperm and also lubrication for sexual intercourse.

Sperm production requires several cell divisions.

- Gametes: are called haploid cells because they contain only 23 chromosomes, rather than the usual 46
- Sertoli cells that make up most of the bulk of the seminiferous tubules.
- Illustration of a sperm
    - Tail= whiplike movements propel the sperm
    - Midpiece= contains mitochondria that produce energy for the sperm
    - Head= contains the male's chromosomes
    - Acrosome= contains the enzymes that assist feritilization.

Recap: the haploid sperm form continuously in the seminiferous tubules from undifferentiated diploid cells called spermatogonia. Millions of sperm from every day throughout a man's life, and a typical ejaculate contains up to 300 million.

Testosterone affects male reproductive capacity

- Male reproductive capacity depends on testosterone, a steroid hormone produced by intersitital cells located between the seminiferous tubules within these testes.
- The production and secretion testosterone depends on three hormones
    - Gonadotropin-releasing hormone (GnRH) from the hypothalamus
    - luteinizing hormone (LH)
    - follicle-stimulating hormone (FSH) from the anterior pituitary gland.
- Feedback control of blood testosterone concentration and sperm production:
    - Negative feedback control loops effectively maintain testosterone concentration (and hence sperm production) relatively constant over time.
    - Negative feedback control occurs at both the hypothalamus and the anterior pituitary.
- When sertoli cells are highly active they secrete a hormone called inhibin that directly inhibits the secretion.

Recap: testosterone stimulates the growth and function of the male reproductive system, aggressive and sexual behavior, and development of secondary sexual characteristics. Blood levels of testosterone are regulated by a negative feedback loop involving GnRH from the hypothalamus and LH and FSH from the anterior pituitary.

2. The female reproductive system produces eggs and supports pregnancy

- The female reproductive organs (the ovaries), produce mature oocytes and release them one at a time on a cyclic basis.
- Fertilization of the oocyte (if it occurs) takes place in the oviduct.
- The fertilized egg makes its way to the uterus, where it implants and begins to develop into a fetus.
- The vagina contains glands that produce lubricating fluid during sexual arousal.
- The hormone estrogen causes the mammary glands to enlarge at puberty.

Ovaries release oocytes and secrete hormones

- The primary female reproductive organs are the two ovaries, which release the female gametes, immature eggs called oocytes.
- The ovaries also secrete the female sex steroid hormones, estrogen and progesterone.
- Once released the oocyte is swept into the open end of an oviduct.

The uterus nurtures the developing embryo

- The uterus is a hollow, pear-shaped organ where the embryo grows and develops.
- The inner layer if the uterus, the endometrium is a lining of epithelial tissue, glands, connective tissue and blood vessels.
- The outer layer of the uterus, or myometrium consists of thick layers of smooth muscle
- The narrow lower part of the uterus is the cervix.

Recap: the ovaries secrete estrogen and progesterone, store immature oocytes, and release generally one oocyte at a time at intervals of about 28days. The oocyte travels through the oviduct to the uterus, where implantation occurs if the egg has been fertilized.

The vagina: organ of sexual intercourse and birth canal

- The cervix jons the vagina, a hollow muscular organ of secual intercourse and also the birth canal
- The vagina continuous at the body surface with the female external genitalia, collectively called vulva.
  - An outer larger pair of fat-padded skin dolfs called the labia majora surround and enclose the labia minora, a highly vascular but smaller pair of folds
  - The clitoris, a small organ partly enclosed by the labia minora is important in the female sexual response.

Component	Function
Ovary	Site of storage and development of oocytes
Oviduct	Duct for transporting oocyte from ovary to uterus; also site of fertilization if it occurs
Uterus	Hollow chamber in which embryo develops
Cervix	Lower part of the uterus that opens into the vagina
Vagina	Organ of sexual intercourse, produces lubricating fluids, also the birth canal
Clitoris	Organ of sexual arousal.

Mammary glands nourish the infant

- Mammary glands: modified sweat glands that technically are part of the skin, or integulentary system.
- Both estrogen and progesterone prepare the glands for lactation, or the production of milk, late in pregnancy.

Recap: the vagina is the female organ of sexual intercourse and the birth canal; around its opening are the structures of the vulva. Mammary glands are accessory organs that produce and store milk.

3. Menstrual cycle consists of ovarian and uterine cycles

- Every month, the ovaries and uterus go through a pattern of changes called the menstrual cycle.
  - 28 days, controlled by hormones.
  - A complete menstrual cycle consists of two linked cycles, the ovarian cycle and the uterine cycle.

- The cyclic changes in the female reproductive system are called the menstrual cycle. The menstrual cycle consists of an ovarian cycle that mature oocytes, and a uterine cycle in which the uterus prepares for pregnancy.
- The menstrual cycle is controlled by the hormones estrogen, progesterone, LH, and FSH. A surge in LH secretion triggers ovulation.

The ovarian cycle: oocytes mature and are released

- The ovarian cycle is a regular pattern of growth, maturation and release of oocytes from the ovary.

- The ovarian cycle: approximately a dozen primary follicles start this process each month, but generally only one completes it. For any particular primary follicle the events take place in one location, but for clarity the events are shown as if they migrate around the ovary in a clockwise fashion.
    - 1. Immature follicle
    - 2. Zona pellucid develops around the primary oocyte
    - 3. Fluid-filled antrum develops
    - 4. Follicle matures.
    - 5. Ovulation. Follicle ruptures releasing the secondary oocyte with its polar body and granulosa cells.
    - 6. Corpus luteum forms from ruptured follicle
    - 7. Corpus luteum degenerates if pregnancy does not occur.

Recap: During the ovarian cycle, a primary oocyte within a developing follicle divides once to form a secondary oocyte. The follicle ruptures, releases the oocyte, and forms the corpus luteum that secretes progesterone and estrogen.

The uterine cycle prepares the uterus for pregnancy

- Uterine cycle is a series of structural and functional changes that occur in the endometrium of the urterus as it prepares each month for the possibility that a fertilized egg may arrive.
    - Day 1-5: menstrual phase.
        - Menstruation is the process by which the endometrial lining disintegrates and its small blood vessels rupture.
    - Day 6-14: proliferative phase.
    - Ovulation: occurs around day 14
    - Day 15-28: secretory phase.
- PMS premenstrual syndrome: group of symptoms often associated with the premenstrual periode, incl food cravings, mood swings, anxiety, back and joint pain, headaches and water retention.

Recap: Rising levels of estrogen cause the endometrium to profilate. If pregnancy does not occur, hormone levels fall and the endometrial layer disintegrates and is shed, a process known as menstruation.

Cyclic changes in hormone levels produce the menstrual cycle

- Regulation of the menstrual cycle:

- During the first half of the cycle LH and FSH stimulate the follicular growth and development.
- The growing follicle secretes estrogen, which partially inhibits LH secretation.
- Shortly before the midpoint of the cycle, estrogen from the mature follicle triggers the LH surge, which in turn triggers ovulation.
- In the second half of the cycle, estrogen and progesterone from the corpus luteum again inhibit LH and FSH secretion, preventing maturation of another follicle until it is determined that pregnancy has not occurred

Than the cycle can begin again.

Recap: Ovulation is triggered by a surge of LH, which in turn is caused by the positive feedback effect of a high concentration of estrogen from the maturing follicle. During the second half of the menstrual cycle, sustained high levels of estrogens and progesterone inhibit further ovulation.

4. Human sexual response, intercourse and fertilization

1) Excitement increased sexual awareness and arousal
2) Plateau intense and continuing arousal
3) Orgasm the peak of sexual sensations
4) Resolution the abatement of arousal.

- Both males and females are aroused by certain stimuli and respond in ways that facilitate intercourse and ejaculation. In males, the penis swells and hardens. In females, glandular secretions provide lubrication.
- Both males and females experience a pleasurable reflex event called an orgasm. Orgasm is accompanied by ejaculation, or the expulsion of semen, in the male.
- Sperm deposited in the vagina during intercourse make their way through the cervix and uterus and migrate up to the oviducts to the egg . Only one fertilizes the egg.

The male sexual response

- Erection occurs when neutral activity relaxes arterioles leading into vascular compartment within the penis.
- At some point sexual arousal becomes so great that orgasm occurs. An orgasm is a brief, intensely pleasurable reflex event that accomplishes ejaculation, or expulsion of semen.
- During the resolution phase, the erection subsides and breathing and heart rate return normal.

The female sexual response

- × The female orgasm, consists of rhythmic and involuntary muscular contractions. Contractions of the uterus and vagina are accompanied by intense feelings of pleasure and sensations of warmth and relaxation.

Recap: women and men experience the same four phases of sexual responsiveness. Sexual arousal in the male results penile erection that leads to orgasm and ejaculation. Females experience sexual arousal and pleasurable orgasms marked by rhythmic muscular contractions.

Fertilization: one sperm penetrates the egg

Recap: during ejaculation, the male deposits several hundred million sperm in the vagina. Fertilization of the egg by a single sperm occurs within five days, if it occurs at all.

5. Birth control methods: controlling fertility

- The most effective methods of preventing pregnancy are abstinence and female or male surgical sterilization. Sterilization should be considered permanent, though it may be reversible.
- Other effective of birth control include intrauterine devices (IUDs) and manipulation of hormone levels with pills, patches, injections, or vaginal rings.
- Moderately effective methods of birth control include include condoms, cervical caps and diaphragms, and various spermicides. The "natural" methods (withdrawal and periodic abstinence) ate the least effective.
- Morning-after pills are now available to be used as emergency contraceptives up to 72 hours after intercourse.

Abstinence: not having intercourse

- × The only complete effective method of birth control is to not have sexual intercourse at all.

Surgical sterilization: vasectomy and tubal ligation

- × Vasectomy: small incisions are made in the scrotum and each ductus deferens is tied in two places and cut.
- × Tubal ligation: an incision is made in a woman's abdominal wall, the two oviducts are located and each is tied and in two places cut.

Hormonal methods: pills, injections, patches and rings

- × Manipulation of hormone levels provides reasonably effective and safe methods of birth control.

Recap: Abstinence and male or female surgical sterilization are highly effective methods of birth control. Hormonal methods – pills, injections, patches, and rings – are also relatively effective but can have side effect.

IUDS are inserted into the uterus

- × Small pieces of plastic or metal that are inserted into the uterus by a health care provider.
- × Prevents either fertilization or implantation of the fertilized egg in the uterine wall.

Diaphragms and cervical caps block the cervix

- Are latex devices that a woman inserts into the vagina
- Prevent sperm from entering the uterus.

Chemical spermicides kill sperm

- Destroy sperm

Condoms trap ejaculated sperm

- One of the most popular

Recap: Physical barriers (diaphragms, cervical caps, and condom) and chemical spermicides are moderately effective, and a few afford some protection against disease. IUDs, although more effective against pregnancy, are also more risky.

Withdrawal and periodic abstinence

- Not very affective
- Withdrawal: means that the man withdraws his penis from the vagina at just the right moment before ejaculation so that ejaculation occurs outside the vagina.
- Periodic abstinence: rely on the fact that fertilization is possible for only a limited time in each menstrual cycle defined by the life span of sperm and the time during which an oocyte can be fertilized after ovulation.

Recap: Withdrawal and periodic abstinence are not effective forms of birth control in the long term.

Pills that can be used after intercourse

Elective abortion

- **An elective abortion is an elective termination of a pregnancy.**
  - **Early stage use of mifeprex**
  - **Vacuum suctioning of the uterus**
  - **Surgical scraping of the uterine lining**
  - **Infusion of a strong saline solution that causes the fetus to be rejected.**

Recap: Pills can be taken after intercourse to forestall ovulation or prevent a pregnancy from continuing. Abortion is a controversial procedure that terminates a pregnancy electively.

The future in birth control

6. Infertility: inability to conceive

- Infertility is defined as the failure to achieve a pregnancy after a year of trying. Nearly 15% of all couples are infertile.
- For male infertility, the primary option is artificial insemination. When the male has a low count but still some viable sperm, the sperm can be concentrated before insemination. In many cases, donor sperm are used.
- Female infertility may be overcome by several methods. In in vitro fertilization, egg and sperm are combined under laboratory conditions. The fertilized egg is allowed to develop for several days and then inserted into the uterus. In GIFT, the egg and sperm are inserted directly into an oviduct immediately after collection. In ZIFT, the egg and sperm are combined first, and then the fertilized egg is inserted into the oviduct.

Infertility can have many causes

- Pelvic inflammatory disease can make woman sterile
  - Bacteria that migrate from the vagina into the oviducts can inflame the oviducts, leading to scarring and either partial or complete closure of the oviduct
- A common cause of failure to achieve reproductive success even when the couple is fertile is spontaneous abortion, or miscarriage, defined as the loss of a fetus before it can survive outside the uterus.

Recap: Male fertility is an insufficiency of lack of sperm. Causes of female infertility are variable and include failure to ovulate, damage to oviducts, pelvis inflammatory disease, secretions that impair sperm function, uterine tumors, endometriosis, age-related changes and miscarriages.

Enhancing fertility

Recap: A variety of methods are available to improve fertility; the choice varies according to the cause of the infertility. Options include artificial insemination, in vitro fertilization, gamete intrafallopian transfer, zygote intrafallopian transfer, fertility-enhancing drugs, and surrogate motherhood.

7. Sexually transmitted diseases

- Disorders of the reproductive systems fall into four classes:
  - Infertility
  - Complications of pregnancy
  - Cancers and tumors of the reproductive organs
  - Sexually transmitted diseases
- Sexually transmitted diseases (STDs) are transmitted by sexual contact, whether genital, oral-genital, or anal-genital.

TABLE 16.4 P 397

- The common feature of sexually transmitted diseases (STDs) is that they are transmitted during sexual contact. Their disease effects are not necessarily on the reproductive system.
- Bacterial STDs include gonorrhea, syphilis, and Chlamydia. Syphilis is the most dangerous; Chlamydia, the most common. All are treatable with antibiotics.
- Viral STDs include HIV (the virus that causes AIDS), hepatitis B, genital herpes, and genital warts (HPV). HIV is particularly deadly, and there is as yet no cure. There are now vaccines for hepatitis B and HPV.
- Avoiding the diseases caused by STDs is a matter of reducing your risk of exposure and paying attention to (and taking responsibility for) your own health.

Protecting yourself against STDs

- Select your partner wisely
- Communicate with your partner
- Use suitable barriers, depending on the sexual activity in which you engage.

Recap: Major bacterial STDs include Gonorrhea, syphilis, and Chlamydia. If not treated, gonorrhea and Chlamydia can cause inflammation and sterility; syphilis can cause widespread damage to body systems and eventual death.

Recap: The most dangerous viral STD is HIV. Hepatitis B can be prevented by a vaccine. Genital herpes is irritating but not particularly deadly. HPV can cause warts and is a risk factor for cervical cancer – it, too, can be prevented by a vaccine.

Recap: Yeast, normally present in the vagina, can multiply and cause a yeast infection; trichomoniasis results from infection by the protozoan Trichomonas vaginalis. Pubic lice are tiny arthropods that are transmitted during intimate contact or by contact with clothes or bedding.

Recap: you can reduce your risk for contracting an STD with a little effort. Choose your partner wisely, use a barrier method of birth control, and, if you suspect you have a disease, get tested promptly.

Cell reproduction and differentiation

1. The cell cycle creates new cells

- Cells reproduce by a repetitive cycle called the cell cycle in which one cell grows and then divides in two.
- The cell cycle has two primary phases: interphase and the mitotic phase. During interphase the cell grows and the DNA is replicated. During the mitotic phase, first the nucleus and then the cell divide in two.

- Cell cycle: the cell cycle consists of two distinct periods
  - Interphase and mitoticphase

- Interphase: a long growth period during which the cell grows and DNA is duplicated in preparation for the next division.
  - G1-phase: "first gap" very active cell growth
  - S phase: " synthesis" of DNA. Cell chromosomes are duplicated. Growth at a slower pace
  - G2-phase: " second gap" cell continues to grow slowly as it prepares for cell division.
- Mitotic phase: much shorter period during which the nucleus and then the cytoplasm divide.
  - Mitosis: duplicate DNA is divided into two sets and the nucleus divides
  - Cytokinesis: cytoplasm divides and two new cells called 'daughter cells' are formed.

Recap: Cell reproduction is required for growth and to replace cells throughout life. The cell cycle consists of a long growth phase (interphase), during which the cell's DNA is replicated, and a shorter phase (mitotic phase), during which first the nucleus and then the cell cytoplasm divide.

2. Replication, transcription, and translation: an overview

- DNA is a double stranded string of nucleotides intertwined into a helical shape.

- Chromosomes: 46 separate structures. Contain proteins called histones that confer a certain structure to the chromosome molecule.
- The structure of a chromosome: DNA combines with histone proteins to become long, thin strands of chromatin material. During most of the

cell cycle the chromatin material of a chromosome is not visible within the cell. During mitosis the chromatin material condenses and the duplicated chromosome becomes visible as two identical sister chromatids held together by a centromere. The two sister chromatids separate during nuclear division.

- Gene: is a short segment of DNA that contains the code or recipe, for one or more proteins.
- Transcription: is the process by which the DNA code of a single gene is converted into a complementary single strand of mRNA.
- Translation: the process of converting the mRNA template code intone or more proteins.
- DNA is replicated before every cell division. Within the nucleus genetic code for a protein is first transcribed into mRNA. mRA transfers the code to the cytoplasm, where it is translated into the correct sequence of amino acids for one or more proteins.

- Human DNA is packed into 45 separate molecules called chromosomes
- A gene is the smallest functional unit of a chromosome. A gene contains the code for making a specific protein
- DNA replication is a process in which the two strands of DNA separate and a new complementary copy is made of each strand
- DNA is repaired when it is damaged and is checked for errors after it is replicated
- For a gene to be expressed, the strand of DNA with that gene must be transcribed to create a complementary strand of mRNA. The mRNA leaves the nucleus, attaches to a ribosome, and serves as the template for protein synthesis.
- Translation is the process of making a polypeptide chain (protein) using the mRNA as a template. Three successive bases of mRNA, called a codon, code for a particular amino acid.
- The amino acid building blocks for the polypeptide chain are captured in the cytoplasm by tRNA, brought to the mRNA, and attached to each other by ribosomal enzymes.

Recap: Human DNA is organized and arranged on 46 chromosomes within the cell nucleus. A gene is the smallest unit of DNA. Before a cell divides, its DNA is duplicated during the process of replication.

Replication: copying DNA before cell division

- Replication: DNA must be duplicated so that the two new cell resulting from the division each haven an identical get of genes.
- Fig 17.5 !

Mutations are alterations in DNA

- Mutations: alternations in DNA. Mutations may result from mistakes made during DNA replication

Mechanisms of DNA repair

- DNA repair mechanisms play a crucial role in the survival of an organism and its species. These mechanisms are quite efficient unless they are overwhelmed by massive damage.

Recap: During replication, the two strands of DNA unwind and separate from each other. Each strand serves as a template to form a new complementary strand. Enzymes called DNA polymerases add new nucleotides to each of the old strands in order to build to complete molecules of DNA from one.

Recap: mutations may result from mistakes in DNA replication of from physical of chemical damage. Repair mechanisms remove and replace damaged DNA, if possible, before replication.

Transcription: converting a gene's code into mRNA

- Transcription is similar to the process of DNA replication with the following exceptions:
  - Only the segment of DNA representing a single gene unwinds, as opposed to the entire molecule
  - RNA is singe-stranded, so that only one of the two strands of DNA actually carries the genetic code specifying the synthesis of RNA
  - One of the four complementary base pairs of RNA is different from those of DNA: uracil replaces thymine.
  - The sugar group of RNA is ribose rather than desoxyribose.

- Introns: The primary transcript is "edited" by enzymes that snip out the sections that do not carry any useful genetic information
- Exons: leaving only the sequences that do carry genetic information
- The rna molecule produced from the primary transcript is called messenger RNA because it contains a message, in the form of a template, that can be "translated" into a specific sequence of amino acid that constitutes particular protein
- Note the following important points:
  - Several different codons can specify the same amino acid because there are more possible codons that there are amino acids.
  - The codon AUG specifies a ' start ' code and three others specify ' stop' codes. These are needed to specify where to begin and end the protein.

Recap: transcription converts short segments of DNA representing single genes into a readable and transportable mRNA code. Only a portion of the DNA molecule unwinds, and only one strand is used to make single-stranded RNA. In the final edited mRNA molecule, three successive bases, called a codon, encode for a particular amino acid.

Translation: making a protein from RNA

- Translation: the process of using mRNA as a template to translate, the mRNA code into a precise sequence of amino acids that composes a specific protein.

- Transfer RNA (tRNA) are small molecules that carry the code for just one amino acid. They also carry an anticodon, a base triplet that is the complementary sequence to a codon of mRNA.
    - Function: capture single amino acids and then bring them to the appropriate spot on the mRNA chain. 7

- Ribosome: consists of two subunits composed of ribosomal RNA.
    - Function: to hold the mRNA and tRNA in place while joining the amino acids.

- Translation occurs in three steps:
    - Initiation: initiator tRNA binds to the smaller of two ribosome subunits and to the mRNA molecule. → move along the mRNA until they encounter "start" (AUG) codon, at this point they are joined by a larger ribosomal subunit to form the intact ribosome, which holds the mRNA in place while the tRNAs bring amino acid to it.
    - Elongation: a tRNA molecule carrying the next appropriate amino acid binds to the ribosome and to mRNA. The tRNA molecule is then released to find another amino acid.
    - Termination: there is no tRNA anticodon corresponding to a 'stop' codon on mRNA. When a 'stop' mRNA codon is encountered, the ribosomal subunits and the newly formed peptide chain detach from the mRNA.

Recap: translation is a three-step process (initiation, elongation, and termination) by which proteins are assembled according to an mRNA code. In the process, tRNA molecules are used to capture the amino acids in the cytoplasm specified by each mRNA codon. The amino acids are connected together on a ribosome, which binds both mRNA and tRNA.

3. Cell reproduction: one cell becomes two

Mitosis: the division of the nucleus

- Fig 17.9
- Prophase: begins when the duplicated chromosomes become first visible
- Metaphase: the duplicated chromosomes align on one plane at the center of the cell.

- × Anaphase: the duplicate DNA molecules separate and move toward opposite sides of the cell
- × Telophase: begins when the two sets of chromosomes arrive at opposite poles of the cell

Cytokinesis divides one cell into two identical cells

Recap: During cytokinesis, a contractile ring of microfilaments pinches the cell into two cells. Each daughter cell contains a nucleus identical to that of the parent.

- × Cytokinesis is the process by which a cell divides to produce two daughter cells.

> - Mitosis is a sequence of events in which the replicated chromosomes are separated to form two new genetically identical nuclei.
> - Cytokinesis is the process whereby the cell divides into two new cells, each with one of the new nuclei produced by mitosis and roughly half of the cell's organelles and mass.
> - Meiosis is a sequence of two cell divisions that produce haploid cells. Meiosis occurs only in cells destined to become sperm or egg. Crossing-over during meiosis mixes the genes of homologous chromosomes, and subsequent cell division reduce the number of chromosomes by half.

Mitosis: produces diploid cells, and meioses produces haploid cells

- × Diploid cells: human cells with 46 chromosomes. → there are 22 pairs of autosomes plus the sex chromosomes X and Y
- × Haploid cells: ex: sperm and eggs. They have only one set of 23 chromosomes .
- × Meiosis: a sequence of two successive nuclear division in which the human genes are mixed, reshuffled and reduced by half.

Recap: Mitosis is the process by which the cell nucleus containing duplicated chromosomes divides in two. During mitosis, the sister chromatids of a duplicated chromosome are separated, resulting in two daughter cells with complete sets of DNA. The duplicated chromosomes become visible in prophase, align along the center of the cell in metaphase, are pulled apart in anaphase and move to opposite sides of the cells and become surrounded by new nuclear membranes in telophase.

Meiosis: preparing for sexual reproduction

- × The two successive nuclear and cell divisions of meiosis are called meiosis I and meiosis II.
- × Fig 17.11

Sex differences in meiosis: four sperm versus one egg.

- × Fig 17.12

Recap: meiosis is a two-step process in which the nucleus and cell divide twice, producing sperm or eggs with the haploid number of chromosomes. Crossing-over ensures that sperm (and eggs) are genetically different from each other because they contain a mixture of genes from each parent.

4. How cell reproduction is regulated

- What causes such different and sometimes changing rates of cell divisions?
- We do know that cells have an internal control mechanism that undergoes cyclic changes, and that the control mechanism can be stopped at certain checkpoints by signals from inside or outside the cell

Divide constantly and rapidly throughout life	
Skin cells	Skin is continually being formed from deep layers. The outermost layer of dead cells is constantly being sloughed off.
Most epithelial cells	Epithelial cells lining the inner surfaces of body organs such as the digestive tract and the lungs are exposed to frequent damage and must be replaced.
Bone marrow cells	Stem cells in the bone marrow produce red blood cells and white blood cells throughout life. WBC production can be increased as part of the immune response
Spermatogonia (after puberty)	Spermatogonia divide to produce sperm throughout life in the adult male. The rate declines with age.

Will divide under certain circumstances	
Liver cells	Liver cells don't normally divide in adulthood but will do so if part of the liver is removed.
Epithelial cells surrounding the egg	Called granulosa cells, they are quiescent for most adult life. They begin to divide as the follicle matures.

Normally do not divide in adulthood	
Nerve cells	Although there are exceptions, most human nerve cells apparently do not divide in adulthood.
osteocytes	Mature bone cells called osteocytes become trapped within the hard crystalline matrix of bone

Muscle cells	The commonly held view is that most muscle cells do not divide in adulthood or divide very slowly.

- Cell reproduction is regulated in part by selective gene expression. Selective gene expression is controlled by regulatory genes.
- The cell cycle may be influenced by the physical and chemical environments both inside and outside the cell.

Recap: an internal cyclic control mechanism regulates the cell cycle. The cycle can be stopped at certain checkpoints by internal surveillance systems and is influenced by conditions outside the cell.

5. Environmental factors influence cell differentiation

× What causes the cells to change form and function?

- Differentiation is the process by which cells become different from each other, acquiring specialized forms and functions
- Because all cells have the same set of genes, differentiation in the early embryo must be triggered be environmental influences
- Cell differentiation later in development can be influenced by environmental cues, but it also depends on the developmental history of the cells that preceded it.

Differentiation during early development

Recap: Differentiation is the process whereby cells become different from each other. During early development, environmental influences trigger differentiation.

Differentiation later in development

Recap: some genes are expressed only at certain stages of development; for this reason, genetic mutations during early development can be particularly damaging. Later in development hundreds of different genes may be expressed by various types of cells. Agents that can harm a fetus include cigarette smoke, alcohol, legal and illegal drugs, chemicals, radiation, and bacterial and viral infections.

Cancer: uncontrolled cell division and differentiation

1. Tumors can be benign or cancerous

- Normal cells have two key characteristics: (1) their rates of division are kept under control, and (2) most remain in one location in the body.
- A mass of cells that is dividing more rapidly than normal is called a tumor. Some tumors are benign.

- Hyperplasia: any increase in the rate of cell division
- Tumor or neoplasm: discrete mass made by rapidly dividing cells.
  - Benign tumors: tumors that remain in one place as a single well-defined mass.
  - Development of a benign tumor: a begins tumor begins when a cell becomes genetically altered and begins to decide more frequently than normal. The mass enlarges but stays well contained, generally by a capsule of normal cells.

2. Cancerous cells lose control of their functions and structures

- Cancer develops when cells divide uncontrollably, undergo physical changes, and no longer adhere to each other
- Eventually some cancer cells invade nearby tissues. Others metastasize, colonizing distant sites.
- Cancer is the second leading cause of death in the US

- Dysplasia: an abnormal structural change
- The development of a malignant tumor (cancer):
  - A genetically altered cell begins to divide more frequently than normal, resulting in an increased number of cells (hyperplasia)
  - Additional genetic alternations cause some cells to change from (dysplasia) and to lose all semblance of organization or control over cell division and function.
    → As long as the mass stays in one place it is called an in situ cancer.
  - But additional changes in the cells may cause them to break away from the tumor and invade normal tissues or enter the blood or lymph. These invading cells may set up new colonies of cancer(= matastases) at distant sites.
    → a cancer that invades and metastasizes is called a malignant tumor.
- A tumor is defined as a cancer when at least some of its cells completely lose all semblance of organization, structure and regulatory control.

	Benign tumor	In situ tumor (cancer)	Malignant tumor (cancer)
Frequency of	More rapid than	Rapid and	Rapid and completely

cell division	normal	completely out of control	out of control
Cell structure and function	Slightly abnormal	Increasingly abnormal	Very abnormal
Tumor organization	A single mass generally surrounded by a capsule	Still a single mass but increasingly disorganized and not always surrounded by a capsule	Some cells break away to invade underlying normal tissues or to enter the blood or lymph. New tumor colonies (metastases) become established at distant sites

Recap: some tumors are benign, but when tumor cell change form dramatically and divide uncontrollably, the tumor is called cancer. Cancer becomes malignant when cells invade and metastasize, starting new tumors at distant sites.

3. How cancer develops

- Mutations of proto-oncogenes, tumor suppressor genes, and/or mutator genes may contribute to cancer
- Inheritance of one or more mutated genes from your parents may increase your risk of developing certain cancers
- Known carcinogens include some viruses and bacteria, environmental chemicals, tobacco, radiation, and dietary factors, such as faulty DNA replication and internally produced chemicals, can also contribute to cancer.
- Cancer is a multifactorial disease. Perhaps six or more mutations may need to be present before a cell becomes cancerous.

Mutant forms of proto-oncogenes, tumor suppressor genes and mutator genes contribute to cancer.

- Proto-oncogenes: normal regulatory genes that promote cell growth, differentiation, division, or adhesion?
- Oncogenes: mutated or damages proto-oncogenes that contribute to cancer

- Tumor suppressor genes: are regulatory genes that under normal condition apply the brakes to unchecked cell growth, division, or adhesion
- Mutator genes: are involved in DNA repair during DNA replication. When these genes mutate, the cell becomes increasingly prone to errors in DNA replication. As a result, the cell may accumulate mutations in other genes.

Recap: Proto-oncogenes and tumor suppressor genes normally control the rate of cell division. Mutator genes are involved in DNA repair. Mutations of any of these genes may contribute to cancer.

A variety of factor can lead to cancer

- A carcinogen: is any substance or physical factor that causes.

Carcinogen	Source of exposure or types of persons exposed	Type of cancer	Exposure of general population
Tobacco(smoking and smokeless)	Smokers, chewers, people exposed to secondhand smoke	Lung, mouth, pharynx, bladder, cervix, colon, pancreas	Common
Diesel exhaust	Buses and trucks, miners, railroad yard workers	lung	Common
Benzene	Paints, dyes, furniture finishes	Bone marrow(leukemias)	Common
pesticides	Agricultural workers	lung	Common
Ultraviolet light	Sunlight	Skin cancers	Common
Ionizing radiation	Radioactive materials, medical and dental procedures	Bone marrow (leukemias)	Common
Human papillomaviruses	Sexually transmitted	Cervix, penis	Common
Hepatitis B virus	Sexually transmitted	Liver	Less common
HIV	Sexually transmitted	Kaposi's sarcoma	Less common
Hydrocarbons in soot, tar smoke	Firefighters, chimney cleaners	Skin, lung	uncommon

asbestos	Shipyard, demolition and insulation workers, brake linings	Lung, epithelial linings of body cavities	uncommon
Radon	Mine workers, basements of houses	Lung	uncommon

- Viruses and bacteria:
  - HPV→ penis, cervix
  - Hepatitis B/C → liver
  - HIV → Kaposi's sarcoma, non-Hodgkin's lymphoma
  - Epstein Barr virus → Hodgkin's disease and non-Hodgkin's lymphoma
  - Human T cell leukemia/ lymphoma virus → HTLV-1, T-cell non-Hodgkin's lymphoma
- Chemicals in the environment
- Tobacco
- Radiation: the high frequently ultraviolet B rays in sunlight cause over 80 % of all skin cancers, incl. a particularly dangerous cancer of the melanin-producing cells of the skin called melanoma.
- Diet
- Internal factors

Recap: aside from heritable susceptibility, factors that may contribute to the development of cancer include viruses and bacteria, environmental chemicals, tobacco, radiation, dietary factors, and alcohol. Free radicals created during cellular metabolism may also contribute to cancer.

The immune system plays an important role in cancer prevention

- Some cancers apparently can suppress the immune system, and other may have mechanisms for disguising themselves form attack by the immune system.
- Fig 18.6 p 434

Recap: The immune system normally protects us from cancer cells by killing them before they spread. Immune system suppression allows cancers to develop more easily.

4. Advances in diagnosis enable early detection

- Early diagnosis of cancer is an important key to success.

Tumor imaging: x-rays, PET and MRI

- The classic approach to diagnosing a tumor is to view its image, either on an X-ray or with a newer method.
- PET scans employ radioactive substances to create three-dimensional images showing the metabolic activity of body structures.

- MRI scans use short brusts of powerfull magnetic field to produce cross-sectional images of body structures.

Genetic testing can be identify mutated genes

- Already hundreds of new genes and their mutated counterparts have been identified, and tests are being devised to detect them
- Such tests are highly controversial, however and society will have to choose how to use them.

Enzyme test may detect cancer makers

- An enzyme called telomerase is rarely found in normal cells but is present in nearly all cancer cells.
- Some researchers propose that a sensitive test for telomerase in the body fluids could detect the early stages of cancer

5. Cancer treatments

- Many cancers are treatable; early diagnosis is important
- Conventional treatments for cancer include surgical removal of the tumor, radiation, and chemotherapy
- Newer treatments include magnetism and photodynamic therapy to target malignant cells precisely, immunotherapy to activate the patient' immune system, drugs to inhibit angiogenesis and cut off the tumor's blood supply, and molecular treatments that target specific genes.

Conventional cancer treatments: surgery, radiation and chemotherapy

- Classic treatments for cancer incl. surgery, radiation, chemotherapy or a combination of these.
- Healthy cells recover from radiation more readily than cancer cells, but radiation therapy generally does injure or kill some normal tissue.
- Chemotherapy: is the administration of cytotoxic chemicals to destroy cancer cells.
    - In addition to nausea and vomiting, common side effects of chemotherapy incl. hair loss, anemia, and an inability to fight infections.
    - A major problem is: many tumors become resistant to chemotherapeutic drugs, just as bacteria become resistant to antibiotics.

Magnetism and photodynamic therapy target malignant cells

- Magnetism: positioning a powerful magnet at the tumor site and injecting tiny metallic beads into the bloodstream. The beads will be pulled into the tumor and kill the cancer cells.
- Photodynamic therapy: treating cancer with light-sensitive drugs and lasers.

Immunotherapy promotes immune response

    - Immunotherapy: attempts to boost the general responsiveness of the immune system so that it can fight cancer more effectively.

"starving" cancer by inhibiting angiogenesis

- Tumors grow and divide rapidly so they require a great deal of energy.
- Angiogenesis: the growth of new blood vessels
- Anti-angiogetic: against blood vessel growth

Molecular treatments target defective genes

- Some researchers are attempting to inactivate specific genes, or the proteins the encode, to slow the runaway cell division. → future techniques may include gene therapy.

> *Recap: the mainstays of cancer treatment are surgery, radiation, and chemotherapy. Recent advances include magnetism, photodynamic therapy, immunotherapy, drugs to inhibit angiogenesis, and molecular treatments that focus on specific defective genes.*

6. Most cancers can be prevented

18.7 Most cancers can be prevented

> - Some cancers will occur despite our best efforts because we cannot control inherited risk factors
> - However, most cancers could be prevented. The single most effective way to reduce cancer deaths is to reduce the rate of smoking
> - A healthy diet will also decrease your cancer risk. Eat lots of fruits, vegetables, legumes, and grains; reduce your intake of saturated fat, red meat, and salt
> - Other preventive strategies include knowing your family's health history, examining yourself for cancer and getting regular medical screenings, maintaining a healthy weight, avoiding direct sunlight and sunlamps, drinking alcohol in moderation if at all, and staying informed.

- Know your family history
- Know your own body
- Get regular medical screening for cancer
- Avoid direct sunlight between 10 a.m. and 4 p.m.
- Watch your diet and weight
- Don't smoke
- If you consume alcohol; drink in moderation
- Stay informed

> Recap: Most cancers could be prevented; smoking is by far the leading preventable risk factor. Other prevention strategies include knowing you family history, getting regular medical screenings, learning self-examination techniques, avoiding sunlight and sunlamps, watching your diet and weight, drinking alcohol in moderation if at all, and staying informed.

~~Genetics and inheritance~~

~~DNA technology and genetic engineering~~

Development and aging

1. Fertilization begins when sperm and egg unite

- Fertilization: a process that begins when a sperm and egg unite and ends when the zygote is formed

- Sperm and egg meet (and fertilization occurs) in the upper third of the oviduct
- Enzymes in the head of the sperm create a pathway through the corona radiata and the zona pellucida to the egg cell membrane
- Entry of the sperm nucleus triggers the completion of meiosis II by the secondary oocyte. Thereafter the nuclei of sperm and egg fuse, creating a single diploid cell, the zygote.

The journey of the egg and sperm

- Egg moves slowly down the oviduct
- The sperm encounters many hazards on their journey towards the egg
  - First: they must pass through the mucus that blocks the cervical opening & cross the vast expanse of the uterus.
  - Then: they must locate & enter the correct oviduct
  - Along the way they must tolerate the acidic pH of the vagina,avoid bacteria & white blood cells roaming the uterine lining.

Recap: Sperm must swim from the vagina, where they are deposited, through the uterus and up the correct oviduct to meet the egg. Relatively few sperm survive the journey.

One sperm fertilizes the egg

- Before fertilization, the egg = a secondary oocyte (started out but not finished the second stage of meiosis)
- 2nd stage of meiosis isn't complete until a sperm makes contact with the egg and fertilization begins.

- When a sperm encounters the egg, the tip of the spermhead (=acrosome) releases enzymes
    - → enzymes digest a path for the sperm between the granulosa cells of the corona radiate & through the zona pellucida to the oocyte plasma membrane.

- Combination of lock and keys: causes the plasma membrane of egg and sperm to fuse so the nucleus of the sperm can enter the egg.

Fertilization:

- begins when the sperm's nucleus enters the egg. The entry of one sperm triggers the release of enzymes from granules located just inside the egg. These enzymes produce changes in the zona pellucida that make it impenetrable to all other sperm. One sperm nucleus will enter the cell
- is complete when the haploid nuclei of sperm and mature ovum join, forming a single diploid cell with 46 chr. (= the zygote)

Recap: when sperm contact the egg they release enzymes that clear a path through the corona radiata and zona pellucida. Fertilization begins when one sperm's nucleus enters the oocyte and ends when the haploid nuclei of sperm and eggs fuse, creating a new diploid cell.

Twins may be fraternal of identical

- Fraternal twins: two oocytes ovulated at different cycles, and each is fertilized by a different sperm.
    - Twins are as different as any children by the same parents
- Identical twins: genetically identical, they arise from a single zygote. Occurs when a single fertilized egg divides in two before differentiation has begun.

Recap: fraternal twins result from the fertilization of two separate eggs. Identical twins occurs when a single fertilized eggs divides in two before differentiation has begun.

2. Development: cleavage, morphogenesis, differentiation, and growth

- Development begins by a process called cleavage and then proceeds with morphogenesis, differentiation, and growth
- The periods of development prior to birth are known as pre-embryonic (the first two weeks), embryonic (weeks three through eight), and fetal (weeks nine to birth)

- Cleavage: a series of cell divisions without cell growth of differentiation during the first 4 days following fertilization. Cleavage produces a ball of identical cells.
- Morphogenesis: the organism undergoes dramatic changes in shape and form.
- Differentiation: individual cells, take on specialized forms and functions. Dedifferentiation of cells is the primary cause of morphogenesis.
- Growth

Recap: The four processes associated with development are (1) cleavage, a series of cell divisions producing a ball of identical cells; (2) morphogenesis , a sequence of physical changes; (3) differentiation, as cells assume specialized forms and functions; and (4) growth in size. Pregnancy is divided into three trimesters.

3. Pre-embryonic development: the first two weeks

- during the first two weeks of development, the single cell develops into a hollow ball with an embryonic disk in the center that will eventually become the embryo
- at about one week the pre-embryo (now called a blastocyst) begins to burrow into the uterine wall, a process called implantation

- The conceptus is known informally as a pre-embryo because many of the cells are destined to become part of the placenta, not the embryo

- 4th day: morula → into the uterus → differentiation→ blastocyst
- Blastocyst: a hollow ball comprising
    - An outer sphere of cells (thropoblast)
    - A hollow central cavity
    - A group of cells; the inner mass cells.
- Day 6 + 7 : implantation; the blastocyst becomes buried within the endometrium
- 2nd week:
    - Amniotic cavity with amniotic fluid
    - Embryonic disk → endoderm/ectoderm

- Ectopic pregnancy: the blastocyst implants outside the uterine cavity.

Recap: During pre-embryonic development, successive cleavages yield a morula. Early stages of differentiation and morphogenesis cause the morula to become a blastocyst, which implants in the lining of the uterus. The embryonic disk is destined to become the embryo.

4. Embryonic development: weeks three to eight

- Embryonic development is marked by the presence of three primary germ layers (ectoderm, mesoderm, and endoderm) in the embryonic disk
- During development the embryo is completely surrounded by two membranes. The amnion contains amniotic fluid, and the chorion develops into fetal placental tissue. Two other membranes (the allantois and the yolk sac) have temporary functions only.
- By the fifth week the embryo begins to take on distinctly human features
- By the eight week the placenta and umbilical cord circulation are fully functional, and male or female gonads have begun to develop

- Tissues and organs derive from three germ layers
  - Ectoderm: outermost layer, the one exposed to the amniotic → skin, nervous system, hair, nails, …
  - Mesoderm: the middle layer → muscle, bone, connective tissue, kidneys, testes, ovaries,…
  - Endoderm: innermost layer → liver, pancreas, alveoli of the lungs, urethra, vagina, glands,…

Recap: By the beginning of the embryonic development the embryo compromises three primary germ layers, called ectoderm, mesoderm, and endoderm, that ultimately give rise to fetal tissues an organs

Extra – embryonic membranes

- Amnion: innermost layer: " bag of water" → absorb physical shocks
- Allantois: a temporary membrane that helps form the blood vessels of the umbilical cord.
- Yolk sac: a small sac that hangs from the embryo's ventral surface. Becomes a part of the fetal digestive tract.
- Chorion: the outermost layer. Forms structures that will be part of the exchange mechanism in the placenta

The placenta and umbilical cord

- Placenta: is the entire structure that forms from embryonic tissue and maternal tissue
  - Effective filter, endocrine organ
- Umbilical cord: the two-way lifeline that connects the placenta to the embryo's circulation

Recap: Four extra-embryonic membranes serve varying functions: (1) the amnion cushions the fetus and preserves it from dehydration; (2) the allantois forms blood vessels of the umbilical cord; (3) the yolk sac forms part of the digestive tract and produces fetal blood cells and reproductive germ cells; (4) and the chorion secretes hCG and forms structures that will become part of the placenta. The placenta is the site of nutrient and gas exchange between embryo and mother, and it secretes hormones. The umbilical cord joins the embryo to the placenta.

The embryo develops rapidly

- Embryonic development during 3th and early 4th week
  - Day 14: flat embryonic disk
  - Day 15: embryo begins to elongate and the primitive streak of ectoderm appears
  - Day 19-23: mark the appearance of a neural groove of ectoderm. Somites develop in the mesoderm → bone, muscle, skin
  - Day 25: pharyngeal arches that will contribute to structures on the head become visible.
- Week 4: the future head is prominent, the position of the eyes becomes apparent, the heart and neural tube are forming and limb buds appear.
- Week 8: the embryo is now distinctly human in appearance. Face, limbs, hands and feed are well formed. Circulatory system is functional.

- Miscarriage: spontaneous termination of pregnancy followed by expulsion of the embryo.

Recap: Embryonic development is rapid an dramatic. By the fifth week the embryo is becoming distinctly human in form, and by eight weeks it is an inch long. The natural rate of miscarriages through eight weeks of development may be as high as 20%

5. Gender development begins at Six weeks

- Until six weeks and embryo is "sexually indifferent"
- The presence or absence of a Y chromosome determines whether the embryo will become phenotypically male or female

- An undiffentiated urogenital groove has developed, topped by a bud and surrounded by labiosrotal swellings.

  → y-chromosome: male sexual characteristics.
  SRY is switched on, testes begin to secrete testosterone.

  → absence of Y-chormosome: female

Recap: Gender development begins at about 6weeks. The presence of a Y chromosome signals the embryo to develop into a male; the absence of a Y chromosome causes the embryo to develop into a female.

6. Fetal development: nine weeks to birth

- Month 3: kidney, limbs are developed. Liver begins to function
- Month 4: liver and bone marrow → produce red blood cells. Forming the eyes & ears. (female: follicles are forming in the ovaries)
- Month 5: nervous system and skeletal muscles → fetus begins to move. Skin covered with soft downy hair.
- Month 6: fetus could survive outside the uterus. Fetus responses to external sounds. Lungs begin to produce surfactant.
- Months 7 → 9: a period of continued rapid growth and maturation in preparation for birth.

- Months 3-9 are marked by rapid growth and development of the organ systems. By the fifth month the fetus begins to move
- By the sixth month, life outside the womb is possible with good medical care

Recap: The period of fetal development extends from nine weeks to birth at 38 weeks. Growth is rapid, with the mature fetus weighing approximately 6-7,5 pounds at birth. The fetus begins to move at about five months, and life outside the womb is at least possible by about six months when the lungs begin to produce surfactant.

7. Birth and the early postnatal period

- Birth occurs at about 38weeks of development (nine months)
- The three phases of labor are dilation, expulsion, and afterbirth.
- Shortly after the new born takes its first breath, the newborn's cardiovascular system undergoes substantial changes. Within hours or a few days the umbilical vessels regress and the ductus arteriosus and foramen ovale close, rerouting all blood through the pulmonary circulation

Labor ends in delivery

- Stage1: DELIATION: the cervical opening widens. The amnion may break at this stage
- Stage2: EXPULSION: the fetus passes headfirst trough the cervical canal and the vagina.
- Stage3: AFTERBIRTH: the placenta detaches from the uterus and is expelled along with the remainder of the umbilical cord.

Recap: labor and delivery take about 24 hours or less. The dilation phase is marked by widening of the cervix and increasingly frequent and strong uterine contractions. The fetus emerges in the shorter (one hour or less) expulsion phase. The placenta and umbilical cord are expelled during the afterbirth phase.

Cesarean delivery: surgical delivery of a baby

- Cesarean delivery: surgical delivery of the baby or C-section
  - An incision is made through the abdominal wall and uterus so the baby can be removed quickly

The transition from fetus to newborn

- Taking the first breath?
  - During labor the placental connection to the mother begins to separate reducing gas exchange with the fetus.
  - Clamping the umbilical cord stops gas exchange entirely.
  - Within seconds the carbon dioxide concentration in the fetus rises to the point that the repiratory centers in its brain stimulate repiration. With the enormous effort of one who is being smothered, the infant takes its first breath and cries.
- Changes in the cardiovascular system
  - Unique features of the fetal circulation:
    - Blood enters the fetus via the umbilical vein.
    - Blood leaves the fetus via two umbilical arteries that originate from arteries the lower extremities.
    - In the fetus there is a hole between two arterial chambers of the heart called the foramen ovale. The hole permits some blood to pass from right atrium to the left one, bypassing the pulmonary circulation. The hole closes after birth.
    - In the fetus there is a shunt, or shortcut, from the pulmonary artery directly to the aorta called the ductus ateriosus. Consequentely, most of the blood pumped by the right ventricle into the pulmonary artery bypasses the lungs. The ductus ateriosis closes after birth.

Lactation produces milk to nourish the newborn

- During the first days, the breasts produce a watery milk called colostrums that is rich in antibodies but low in fat and lactose.

Recap: at birth a sharp increase in carbon dioxide causes the newborn to take the first breath. Shortly after birth the umbilical blood vessels and ductus arteriosus regress, and anatomical changes in the heart reroute all blood through the lungs. Prolactin stimulates lactation, and oxytocin stimulates the release of milk during suckling.

8. From birth to adulthood

- Human neonates are relatively helpless because the nervous and muscular systems are not yet mature
- There is a disproportionate increase in the development of the musculoskeletal and nervous system during infancy. The immune system remains relatively immature
- Body shape changes in childhood. The brain achieves 95% of its adult size
- Adolescence is marked by the last spurt of rapid growth and the attainment of sexual maturity

The neonatal period: a helpless time

Recap: The neonatal nervous and muscular systems are not well developed. Neonates are physically helpless and cannot form memories

Infancy: rapid development and maturation of organ systems

Recap: Infancy is marked by rapid growth and continued maturation of organ systems. Infants begin to eat solid foods and to walk. The immune system develops more slowly than other organ systems.

Childhood: continued development and growth

Recap: Brain growth is nearly complete by the end of childhood. Muscle strength and coordination improve, and body form changes to a more adult form.

Adolescence: the transition to adulthood

Recap: Adolescence is accompanied by a growth spurt and by maturation of the reproductive systems. Puberty begins when the hypothalamus matures and starts to secrete GnRH.

9. Aging takes place over time

- most cells have an internal mechanism that limits the number of times they can divide
- cumulative unrepaired cellular damage as a consequence of metabolic activity may limit the life of cells
- aging may affect all organ systems because a decline in one system will affect other systems

What causes aging?

Recap: Aging is a complex process that is still poorly understood. It appears that most cells are limited in how many times they can divide, and that damage may accumulate in cells until they no linger function properly. At the whole-organism level, declines in function of one organ of system may eventually impair other organ systems.

Body systems age at different rates

Recap: The actual pattern of aging in various organ systems is well documented even if we don't fully understand the underlying causes. All organs and organ systems decline in function with advancing age, though not necessarily at the same rate

Aging well

Even if the aging process cannot be stopped, it is certainly possible to improve human health and wellness throughout life. Regular exercise and healthy nutrition are important factors in aging well.

10. Death the final transition

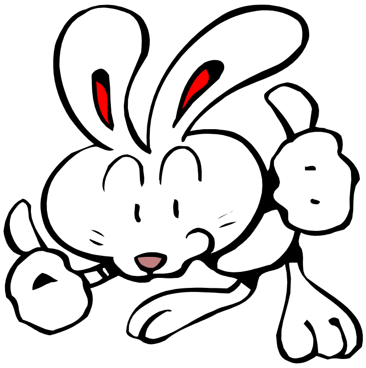
- Death is a process. Death begins with the failure of one or more critical organs systems, leading to the failure of other organ systems and eventually to the death of all cells.

Recap: death is the termination of life. In a complex organism it is a process that can be gradual or brief. Death starts with the failure of one or more critical organ systems and ends ultimately with the inability to maintain an internal environment consistent with cellular life.

~~**Evolution and the origins of life**~~

~~**Ecosystems and populations**~~

~~**Human impacts, biodiversity and environmental issues**~~



Heel goed gedaan! Het is je gelukt! Nu tijd voor een welverdiende pauze (speciaal voor Marjolein)