A&P 1
Homeostasis and Organ Systems

Definitions

Anatomy
- Study of internal and external structure and the physical relationships among body parts

Physiology
- Study of how living organisms perform vital functions

Levels of Organization

Anatomy emerges as each level adds structure and functions to the levels below
- Atoms and Molecules
- Organelles
- Cells
- Tissues
- Organs
- Organ Systems
- Individual Organism

Atoms and Molecules

Lowest rank
- Ions, water, and other molecules interact within and outside the cell

Metabolism is a description of the interactions which occur between molecules within the cell

Organelles

Cytoplasmic structures within the cell
Specialized in a particular aspect of metabolism
- Nucleus, mitochondria

Cells

Smallest units of life capable of reproduction
May become specialized for performing specific functions within the body
- Liver cell, muscle cell

Tissues

Groups of similar cells which perform a particular function
- Myocardium, blood

Organs

Carry out unique functions by combining two or more tissues
- Heart, brain

Organ Systems

Associations among organs that serve broad functions
- Cardiovascular system, central nervous system, reproductive system

Individual Organism

Top of the hierarchy
Emerges from the integral actions of lower levels

Organ Systems

The individual organism depends on the proper function of different organ systems
- Skeletal
- Muscular
- Integumentary
- Cardiovascular
- Lymphatic and Immune
- Nervous
- Endocrine
- Digestive
- Respiratory
- Urinary
- Reproductive

Organ systems are interdependent and interconnected

A variety of physiological mechanisms act to prevent potentially disruptive changes inside the body

Homeostasis

Homeostasis refers to the existence of a stable internal environment
Homeostatic regulation is the adjustment of physiological systems to preserve homeostasis
Two general mechanisms are involved in homeostatic regulation
- Autoregulation

Extrinsic regulation

Autoregulation

Activities of the cell, tissue, organ or organ system change automatically when faced with some environmental variation
Ex. Tissues experiencing oxygen deprivation release chemicals, which cause a local dilation of blood vessels

Extrinsic Regulation

Activities of the nervous system or endocrine system can control or adjust activities of many different systems at the same time
Ex. Exercise induces the nervous system to increase your heart rate and reduce blood flow to unessential organs

Homeostasis

Homeostatic regulation always attempts to keep the characteristics of the internal environment within desirable limits
When homeostatic regulation fails organ systems begin to malfunction
The resulting state is known as illness or disease

END
Homeostasis & Organ Systems

A&P 1
Introduction to Chemistry

CHEMISTRY

Matter occupies space and has mass
Elements - 92 naturally occurring substances
Fundamental substance that cannot be broken down to a different substance

ORGANIZATION OF MATTER

Most of the human body is made up of only four kinds of elements
HYDROGEN--------- H
CARBON---------- C
NITROGEN---------- N
OXYGEN---------- O

TRACE ELEMENTS

P----------Phosphorus
Mg---------Magnesium
K----------Potassium
Ca---------Calcium
Cu---------Copper
S----------Sulfur
Fe----------Iron
I----------Iodine
Na---------Sodium
Cl----------Chlorine

COMPOUNDS

Two or more elements combine
ex: H_20 $C_6H_{12}O_6$ H_2SO_4
Atoms--smallest unit of matter that is unique to a particular element
Subatomic particles
protons
neutrons
electrons

ATOMS

atomic number---number of protons
atomic weight----protons + neutrons
atomic charge----protons - electrons

ELECTRON SHELLS

Electrons exist in specific numbers at certain distances from the nucleus of an atom
Electron shells or orbitals
1st orbital = 2 electrons
2nd orbital = 8 electrons
3rd, 4th, 5th etc

ISOTOPES

Isotopes--atoms in which the number of neutrons are different from the number of protons
C^{12} = 6 protons + 6 neutrons
C^{14} = 6 protons + 8 neutrons

RADIOISOTOPES

Radioisotopes-radioactive isotopes
Unstable, tend to break apart (decay) into more stable atoms
Used in fossil dating and as medical tracers

IONS

Ion--atoms which have lost or gained electrons and thus gained a positive or negative charge
ex: Na^+ 11 protons 10 electrons
ex: Cl^- 17 protons 18 electrons

CHEMICAL BONDING

Union of the electron structure of atoms to form molecules (compounds)
1) **Ionic** bonding
2) **Covalent** bonding
3) **Hydrogen** bonding

Formation of a chemical bond produces a molecular compound
Chemical compounds have different chemical properties than the atoms which make them up
Ex: Na^+ is very explosive in presence of water while Na^+ combined with Chlorine produces common table salt (NaCl)

IONIC BONDING

Bond formed between ions due to their mutual attraction of opposite charges
ex: Na^+ and Cl^-

form NaCl (table salt)

COVALENT BONDING

Electrons are shared
ex: H-H O=O N=N
H_2 O_2 N_2
1) Non-polar covalent
2) Polar covalent

NON-POLAR COVALENT BOND

1) **Non-polar** covalent bond
Electrons are shared evenly

ex: H-H

H_2

POLAR COVALENT BONDING

2) **Polar** covalent bonding
Electrons are more attracted to one atom than another

Electrons are more attracted to oxygen than hydrogen
Electrons spend more time around oxygen than hydrogen

HYDROGEN BONDING

Hydrogen atom reacts weakly with another atom or molecule bonds are easily broken
ex: water molecules are held together by hydrogen bonds
ex: DNA--strands are held together by hydrogen bonds

PROPERTIES OF WATER

H_2O carries a partial charge
due to the extra amount of time that the electron (in its figure eight pattern) spends around oxygen
Hydrophilic - (water loving) polar substances
able to mix with water

Water ----- sugar

Hydrophobic - (water dreading) non-polar substance
unable to mix with water

Water ---- salad oil

Water acts as a solvent
Na^+ Cl^- dissolved in water
Salt is the solute and water is the solvent
Water acts as a solvent
Na^+ Cl^- dissolved in water
Salt is the solute and water is the solvent

ACIDS, BASES, & SALTS

ACIDS
Substances dissolved in water release a proton (H^+)

HCl

BASE
Substances dissolved in water release a hydroxide ion (OH^-)

NaOH

SALTS
Precipitate formed by the reaction of an acid and a base

NaCl

pH SCALE

Measures the concentrations of free H^+ ions
0----------7----------14
acid base
pH of 7
The concentration of H+ ions and OH- ions are equal to each other

ex: water

The greater the H^+ ions the lower the pH

END
INTRO TO CHEMISTRY

A&P 1
Organic Chemistry

CARBON COMPOUNDS

Exceptional bonding properties
can form covalent bonds to other carbons

ORGANIC MOLECULES

carbon chain or ring backbone
1) sugars (carbohydrates)
2) fatty acids (lipids)
3) amino acids (proteins)
4) nucleotides (nucleic acids)
serve as an energy source
serve as building blocks for macromolecules

ORGANIC REACTIONS

Types of Organic Reactions
1) Electron transfer
2) Condensation
3) Hydrolysis

ELECTRON TRANSFER

one or more electrons stripped from one molecule are donated to another molecule
ex. electron transfer phosphorylation

Kreb's cycle

As electrons are passed from one enzyme to another energy is released
An analogy would be a ball bouncing down a staircase

CONDENSATION

through covalent bonding, two molecules combine to form a larger molecule
covalent linkage of molecules in a reaction that can form water
starches and other polymers are formed by repeated condensation reactions

HYDROLYSIS

a type of cleavage reaction which is like condensation in reverse
molecules are cleaved into two or more parts by reaction with water
polymers are hydrolyzed to use the subunits as building blocks or energy sources

MOLECULES OF LIFE

Carbohydrates
Lipids
Proteins
Nucleic acids

CARBOHYDRATES

most abundant biological molecule
- Monosaccharides
- Oligosaccharides
- Polysaccharides

MONOSACCHARIDES

simplest carbohydrate
most are sweet tasting
dissolve readily in water
consist of 5 - 6 carbons in a ring structure
function primarily as an energy source

Examples of monosaccharides
- ribose
- deoxyribose
- glucose
- fructose

OLIGOSACCHARIDES

short chain of two or more covalently bonded sugar units (condensation)
function primarily energy transport and cell membrane operation
disaccharides have two sugar units
- Lactose

milk sugar

- Sucrose

table sugar

- Maltose

POLYSACCHARIDES

branched chain of many sugar units
function primarily in structural support and energy storage

GLYCOGEN

sugar storage molecule in animals
found mostly in liver and muscle tissues

LIPIDS

most contain fatty acid components
- long water-insoluble chains of carbon and hydrogen

dissolve readily in one another
 nonpolar (ether)
do not dissolve in water
 polar
lipids act as the main reservoirs of stored energy
 Triglycerides
 Phospholipids
 Sterols

FATTY ACIDS

long carbon backbone
typically stretch out like long flexible tails when combined with other molecules
 saturated fatty acids
 unsaturated fatty acids

SATURATED FATTY ACIDS

solid at room temperature
single bonds only in the carbon backbone
saturated fatty acids line up in parallel giving the substance a solid consistency
 butter
 lard

UNSATURATED FATTY ACIDS

liquid at room temperature
 oils
required in the human diet
one or more double bonds in the carbon backbone
 double and triple bonds put “kinks” in the tails
 does not pack together and thus imparts fluidity to substances

POLYUNSATURATED FATTY ACID

Many carbon double bonds

LIPIDS

Triglycerides
Phospholipids
Sterols

TRIGLYCERIDES

Butter
Fats
Oils

fatty acid tails attached to a backbone of glycerol
yield twice as much energy as carbohydrates
rich source of stored energy
thick layers of triglycerides also insulate
triglycerides are stored as fat droplets in adipose tissue

PHOSPHOLIPIDS

main components of cell membranes
 backbone of glycerol
 two fatty acid tails which are hydrophobic
 hydrophilic “head” that includes a phosphate group
main components of cell membranes

STEROLS

 steroids
 cholesterol
 hormones
lipids which have no fatty acid tails
rigid backbone of four fused carbon rings
found in cell membranes
Steroids are a class of hormones which act as chemical messengers in the body

CHOLESTEROL

cholesterol gives rise to:
- vitamin D
- estrogen
- testosterone
- bile salts

PROTEINS

polymers of amino acids
20 different kinds of amino acids

CLASSES OF PROTEINS

enzymes
- speed up or slow down chemical reactions

structural
- muscles, bone, hoof, claw, hair

transport
- cell membrane and body fluids

regulatory
- protein hormones

antibodies (immunoglobulins)
- body defenses and immune system

3D STRUCTURE OF PROTEINS

The three dimensional structure of a protein plays an important role in the characteristics of how a protein functions

DENATURATION

breaking the weak bonds of a protein molecule disrupts its three-dimensional shape
hydrogen bonds holding a proteins secondary and tertiary structures intact are easily broken
- changes in pH
- changes in temperature

ex: albumin (protein) in eggs

“egg white”

LIPOPROTEINS

blood proteins combine with cholesterol, triglycerides and phospholipids after a meal

GLYCOPROTEINS

proteins with oligosaccharides covalently bonded to them
oligosaccharide chains may be linear or branched
found primarily attached to animal cell membranes

NUCLEOTIDES

consist of three components
- nitrogen base
- phosphate group
- 5-carbon sugar

ribose

deoxyribose

CLASSES OF NUCLEOTIDES

energy carriers
- ATP
- ADP

coenzymes
- NAD^+
- FAD

chemical messengers
- cAMP

nucleic acids
 DNA
 RNA
delivers energy from one site to another
ATP
 adenosine triphosphate
ADP
 adenosine diphosphate

COENZYMES

transport hydrogen atoms and electrons stripped from other molecules
 NAD^+
 FAD

CHEMICAL MESSENGERS

act as chemical messengers within and between cells
cAMP
 cyclic adenosine monophosphate

NUCLEIC ACIDS

four different kinds of nucleotides are bonded together in large single or double stranded molecules
sequence of the particular bases is unique to each kind of nucleic acid
genetic information is encoded in such base sequences

RNA

ribonucleic acid
single stranded

DNA

deoxyribonucleic acid
double stranded molecule which twists helically like a spiral staircase
hydrogen bonds hold the two strands together

END
ORGANIC CHEMISTRY

A&P 1
Cell Structure

CELL THEORY

smallest entity that retains the characteristics of life
 1) complex organization
 2) metabolic activity
 3) reproduction

GENERALIZATIONS OF CELL THEORY

1) all organisms are composed of cells
2) cells are the basic unit of life
3) new cells arise only from cells that already exist

CELL SIZE

most cannot be seen without the aid of a microscope
 larger cells

"yolk" of bird eggs

fish eggs "caviar"
human eyes have a resolution of about 100 microns

LIGHT MICROSCOPE

The light microscope has a limit of resolution of about 200 nm (0.2 microns)

TEM

The Transmission Electron Microscope (TEM) has a limit of resolution of about 2 nm

SEM

The Scanning Electron Microscope (SEM) also has a limit of 2 nm

TWO TYPES OF CELLS

Eukaryotic cells
1) contains distinctive internal organelles
2) contains nucleus which houses DNA

Prokaryotic cells
1) lack a nucleus
2) bacteria are the only prokaryotic cells

PROKARYOTIC CELLS

1) all bacteria are prokaryotic
2) smallest and simplest of cells
3) many have flagella for locomotion
4) rigid cell wall surrounds the cell membrane supports the shape of the cell
5) irregular shaped DNA region DNA is in ring shape
6) bacteria are metabolically diverse

EUKARYOTIC CELLS

1) more complex cells
2) contain a nucleus with DNA and organelles
3) contain cytoplasm surrounded by a plasma membrane
4) some cells have a cell wall in addition to a plasma membrane plants, fungi

GENERALIZATIONS OF CELL THEORY

cells vary in size, shape and activities
all cells have:

1) *Plasma membrane*
2) *DNA region*
3) *Cytoplasm*
4) *Organelles*

PLASMA MEMBRANE

outer membrane maintains the integrity of the cell
membrane does not however isolate the cell
Cell membrane
"lipid bilayer"
boundary that bars free passage of water soluble substances in and out of the cell
Embedded proteins
carry out membrane functions
types of membrane proteins
1) Passive channels
2) Protein pumps
3) Protein receptors
4) Recognition proteins
5) Adhesive proteins

NUCLEUS

DNA is localized in the cell nucleus

CYTOPLASM

everything enclosed by the plasma membrane except the DNA semi-fluid

ORGANELLES

organelles--internal sacs which have a specific metabolic function
essential in keeping chemical reactions in the cytoplasm separate from each other

NUCLEUS

nucleus sequesters DNA
1) separates DNA from chemical reactions in cytoplasm
2) nuclear membranes control access between nuclear material and cytoplasm

Nuclear envelope has pores to allow passage of messenger units of nucleic acid

NUCLEOLUS

1) assembly of RNA and ribosomes
2) storage of RNA and ribosomes

DNA

instructions for building proteins (enzymes) are contained in DNA
instructions of heredity are distributed in several DNA molecules of various lengths
humans = 46 DNA molecules
DNA is threadlike
prior to cell division the DNA molecules duplicate

CHROMOSOMES

DNA folds and twists into condensed structures called chromosomes

CYTOMEMBRANE SYSTEM

Series of organelles through which lipids and proteins, produced on cytoplasmic ribosomes, pass through in becoming packaged for export

1) Endoplasmic reticulum (ER)
2) Golgi bodies
3) Vesicles
4) Lysosomes

ENDOPLASMIC RETICULUM

1) Rough endoplasmic reticulum
ribbon like structure with ribosomes attached
arranged as flat, stacked sacs

RIBOSOMES

ribosomes are small spherical shaped structures
serve as the “working table” for assembling proteins

2) Smooth endoplasmic reticulum
lacks ribosomes

appears like a system of pipes

A) lipid synthesis

ex: endocrine glands produce steroid hormones

B) inactivate harmful by-products of metabolism and drugs

ex: liver cells

GOLGI BODIES

Resemble stacks of pancakes
flattened sacs in which lipids and protein molecules are modified
modifications allow for sorting and packaging for transport

VESICLES

Sacs which transport or store enzymes, lipids and proteins

1) Peroxisomes
2) Lysosomes_(microbodies)

PEROXISOMES

contain enzymes to break down fatty acids and amino acids
result is the release of hydrogen peroxide
requires catylase to convert hydrogen peroxide to water and oxygen

ex: liver cells degrade alcohol

LYSOSOMES

vesicles of intracellular digestion
contain enzymes which can break down any polysaccharide, protein, nucleic acid and some lipids

TAY-SACS DISEASE

Lysosomal storage disease
lipids accumulate in lysosomes because they cannot be broken down
important in proper function of white blood cells (immunity)
Lysosomes play an important role in aptosis
important in cell reclamation (tadpole tail)

CYTOMEMBRANE SYSTEM

raw materials (amino acids and lipids) are dissolved in the cytoplasm under the instructions of the DNA molecule
polypeptide chains of proteins are assembled from the dissolved raw materials

1) mRNA brings code for protein synthesis from DNA to the ribosome
2) Protein synthesized and packaged by ER in a transport vesicle
3) Transport vesicle carries protein to the Golgi bodies
4) Proteins are modified in the Golgi bodies and transported to the cell membrane
5) Modified proteins are released from the cell by exocytosis

MITOCHONDRIA

contains a series of inner membranes folded repeatedly (cristae)
increases the total surface area available for reactions
use oxygen to assist in liberating energy stored in sugars
energy is used to form ATP molecules which is used for protein synthesis and transportATP-molecule is able to store and transport energy for short periods of time
most numerous in high energy demanding cells
ex: muscles, liver
may have evolved from engulfed bacteria which escaped digestion
contains its own DNA and is able to divide
All your mitochondria come from your mother

CYTOSKELETON

interconnected system of bundled fibers, threads and lattices
extend from the cell membranes, organelles and nucleus
supply internal organization, shape, ability to move, reinforce the cell membrane and hold proteins in place
cytoskeleton consists of microtubles and microfilaments which are assembled from proteins
ex: muscle cells - filaments for contraction
ex: amoeboid movement - white blood cells
ex: cilia action - nasal passages
ex: flagella - sperm cells
ex: centrioles - important in cell division
ex: molecular motors – cell organelle movement

CELL SURFACE SPECIALIZATIONS

Gap Junctions
channels of exchange in animal cells

ex: liver, heart

Junction Proteins
hold cells together in forming tissues

END
CELL STRUCTURE

A&P 1
Cell Membrane

CELL MEMBRANE

cell membrane made up of:
1) Phospholipids
2) Sterols
3) Proteins

4) Glycoproteins

PHOSPHOLIPIDS

cell membrane - semi-permeable lipid bilayer
two layers of Phospholipids

STEROLS

common sterols of cell membranes
Cholesterol (animal cells)

prevent packing of lipid cells in the cell membrane

PROTEINS

Proteins are embedded into the cell membrane
These proteins serve a variety of cell membrane functions

GLYCOPROTEINS

proteins are embedded in the bilayer
glycoproteins - sugar-protein combinations
sugars extend out to the extracellular fluid

FLUID MOSAIC MODEL

membrane bilayer shows fluid behavior
molecules of the bilayer are in constant motion
membrane is composite of molecules allowing a “mosaic description”
cell survival depends on fluidity characteristics of the cell membrane
extracellular fluid temperature decreases cause a stiffening of the cell membrane
disrupts membrane protein function

ROUTES ACROSS CELL MEMBRANES

1) Diffusion / Osmosis
2) Protein Mediated Diffusion
3) Endocytosis and Exocytosis

DIFFUSION

diffusion process is a key factor in movement of substance across cell membranes and through the cytoplasm of the cell
movement of molecules from areas of high concentrations to areas of lower concentrations
net movement of molecules occurs down the concentration gradient
Some molecules are able to diffuse without assistance or consumption of energy
oxygen, carbon dioxide and small molecules with no charge
rate of diffusion is dependent on:
1) steepness of the concentration gradient
2) temperature
3) molecular size
4) electrical gradients
5) pressure gradients

OSMOSIS

movement of water across a semi-permeable membrane in response to solute concentration gradients
some small molecules (like water) pass readily through the cell membrane
Other molecules like glucose must be pumped across the membrane
water concentration gradient is influenced by the number of molecules of solutes that are present on both sides of the membrane
the direction in which water moves across the membrane is influenced by tonicity
tonicity-relative concentrations of solutes in two fluids
water tends to move where solute concentrations are greatest
1) Isotonic=solute concentrations are equal
2) Hypotonic=least solute concentrations
3) Hypertonic=greatest solute concentrations
water molecules move from hypotonic solutions to hypertonic solutions
cells require built in mechanisms for adjusting to differences in tonicity between cytoplasm and their surroundings

without them cells will:

1) shrivel (crenation)

2) burst (lyse)

PROTEIN MEDIATED DIFFUSION

glucose, large water soluble molecules and charged ions
cannot diffuse freely across the cell membrane

A) Passive Transport

B) Active Transport

PASSIVE TRANSPORT

molecules diffuse through non-selective channel proteins
selective carrier proteins can move molecules of a solute across the cell membrane by binding and changing shape
passive transport occurs only down the concentration gradient

ACTIVE TRANSPORT

transport occurs when carrier proteins receive an energy boost from ATP
pump solutes across the cell membrane against the concentration gradient
ex: calcium pump, sodium-potassium pump

cytoplasm concentrations of K+ increase and Na+ decrease

TYPES OF MEMBRANE PROTEINS

1) Channel Proteins
2) Active Transport Proteins
3) Receptor Proteins
4) Recognition Proteins
5) Adhesion Proteins

CHANNEL PROTEINS

does not require any energy investment by the cell
most remain open at all times
acts as a pore for water-soluble ions
may have molecular gates
ex: nerve cells during nerve impulses
1) molecules only move down the concentration gradient
2) does not require any energy input from the cell

FACILITATED DIFFUSION

Does not require energy
Highly selective
Polar compounds such as sugars and amino acids
Diffusion is down the concentration gradient

ACTIVE TRANSPORT PROTEINS

require energy to transport molecules
1) molecules are pumped against their concentration gradient
2) requires an energy input from the cell
a change in shape allows bound substances to pass through the membrane
some may require an energy input to actively pump substances across the membrane

RECEPTOR PROTEINS

have binding sites for hormones
ex: hormone <u>somatotropin</u> binds to receptors which triggers enzymes to activate cell growth and division

RECOGNITION PROTEINS

act as “molecular fingerprints” on the cell surface
self recognition proteins identify cell type to other cells
white blood cells are able to recognize “self” from “non-self”
glycoproteins are extended into the extracellular fluid for easy access for recognition

ADHESION PROTEINS

connect cells together in a given tissue
glycoproteins connect neighboring cells
some may become cell junctions

EXOCYTOSIS AND ENDOCYTOSIS

move materials in bulk across cell membranes

EXOCYTOSIS

cytoplasmic vesicles fuse to the cell membrane and contents are released to the outside of the cell

ENDOCYTOSIS

1) Phagocytosis
2) Pinocytosis
region of the cell membrane sinks inward and balloons around substances, pinching itself off into a sealed vesicle which transports or stores the contents

PHAGOCYTOSIS

"cell eater"
ex: amoeba, white blood cells (macrophage)

lobes of cytoplasm wrap around the trapped item and seal together

newly formed vesicles fuse with lysosomes for digestion

PINOCYTOSIS

"cell drinking"
ex: intestinal cell taking up liquid droplets

END
Cell Membrane

A&P 1
Metabolism

METABOLISM

Metabolism - the capacity to acquire energy and use it to build, store, break apart and eliminate substances in controlled ways
Energy - the capacity to make things happen
cells secure, use and lose energy
cells cannot create energy
cells must get energy from somewhere else
Most energy available for energy conversion is stored in covalent bonds
glucose, starch, glycogen and fatty acids are rich in covalent bonds
When molecules are broken apart there is a release of energy which is available to make things happen

CHEMICAL REACTIONS

Many reactions in the cell result in the production of ATP or the use of ATP
ex: Cellular respiration
$C_6H_{12}O_6 + O_2 \dashrightarrow CO_2 + H_2O$

METABOLIC PATHWAYS

Orderly sequence of reactions with specific enzymes acting at each step
If the sequence is interrupted the pathway does not continue and by-products begin to accumulate

BIOSYNTHETIC PATHWAY

Biosynthetic (anabolism) - small molecules are assembled into large molecules of higher energy content
Requires the input or use of ATP
ex: amino acids ----→ proteins
fatty acids ----→ lipids
glucose ----→ starch

BIODEGRADATIVE PATHWAY

Biodegradative (catabolism) - large molecules are broken down to smaller molecules of lower energy content

ex: starch ----→ glucose
protein ----→ amino acids
lipids ----→ fatty acids

METABOLIC REACTION PARTICIPANTS

All reactions have these participants:

Substrates
End products
Intermediates
Enzymes
Cofactors
Energy carriers

Substrates - enter into reactions (reactants)
End products - substance at the end of a reaction
Intermediates - compounds formed between the start and the end of a metabolic pathway
Enzymes - proteins that catalyze reactions
Cofactors & Coenzymes - metal ions or organic molecules that assist enzymes
Energy carriers - move or temporarily store energy

ENZYMES PROPERTIES

1) Able to speed up reactions (million fold)
described as catalytic molecules
2) Enzymes are not used up in the reactions they mediate
3) Enzymes are highly specific about the reactions they will affect
ex: thrombin (enzyme) essential for blood clotting

breaks only a peptide bond between two amino acids (arginine and glycine)

4) Enzymes are used in both directions of a reaction
6) Enzymes are able to lower the Activation energy necessary to make its substrates react
7) Enzyme function is based on shape

EFFECTS OF pH ON ENZYME ACTIVITY

Enzymes function best within a certain pH range
most function best at pH=7 (neutral)

exception: pepsin (a stomach cell enzyme) works best at low pH

ALLOSTERIC ACTIVATION

Factors which assist the action of enzymes are called Cofactors

1) Coenzymes
2) Metal ions
3) Effectors

COFACTORS

1) Coenzymes - complex organic molecules
most are derived from vitamins
ex: NAD+ and FAD
2) Metal ions
ex: Fe++, Cu+
3) Effectors
Effectors are factors which may affect how an active site functions

Ex. Change shape

COMPETITIVE AND NON-COMPETITIVE INHIBITION

Inhibition at the active site prevents an enzyme substrate complex from forming

NON-COMPETITIVE INHIBITION

Negative feedback is the term used to describe how the accumulations of the by-products of a reaction interfere with the continued enzyme-substrate reaction

ELECTRON TRANSFERS

Glucose molecules are broken down in a series of steps by the cell
The glucose breakdown leaves energy released and intermediate by-products at each step
energy release is accomplished by electron transport systems (ets)
electrons are accepted (reduced) at higher energy levels and released (oxidized) to lower energy levels
as electrons move down the staircase energy is released at each step
as electrons move down the staircase energy is released at each step

STRUCTURE AND FUNCTION OF ATP

ATP - Adenosine TriPhosphate
energy from glucose breakdown or light is converted to ATP
phosphate groups with covalent bonds are unstable and easily broken

END OF METABOLISM

A&P 1
Energy Releasing Pathways

PATHWAYS LEADING TO ATP FORMATION

1) Aerobic respiration
   requires oxygen
   most cells are able to perform
2) Anaerobic respiration
   does not require oxygen
   many bacteria and protists are able to perform
      a) Fermentation
      b) Electron Transport

All three types of respiration begin with glycolysis in the cell cytoplasm
Glucose is split and rearranged into two pyruvate molecules

AEROBIC RESPIRATION & FERMENTATION

Aerobic respiration
  Produces the most ATP for each glucose
  yields 36 ATP from 1 glucose

$C_6H_{12}O_6 + 6\ O_2$ -----> $6\ CO_2 + 6\ H_2O$ + energy

Fermentation (anaerobic)
  yields only 2 ATP from 1 glucose

STAGES OF AEROBIC RESPIRATION

1) Glycolysis
   glucose-----> pyruvate
   occurs in the cytoplasm
2) Kreb's Cycle
   pyruvate-----> CO_2 and H_2O
   occurs in the mitochondria
3) Electron Transport Phosphorylation
   yields most of the ATP
   also occurs in the mitochondria

GLYCOLYSIS

6 carbon glucose molecule is broken down to a 3 carbon pyruvate
glycolysis process invests:
  1 glucose molecule
  2 ATP units
glycolysis process yields:
  4 ATP units
  2 NADH
  2 pyruvate molecules

KREB'S CYCLE

Named after Hans Adolf Kreb
Also called the Citric Acid Cycle
Takes place in the mitochondria

KREB'S CYCLE FUNCTIONS

Functions:
  1) Load electrons and H^+ onto the NAD^+ and FAD molecules
     Forming NADH and $FADH_2$

2) Produce 2 ATP units
3) Rearrange intermediates into oxaloacetate to recycle the carbon chains

Coenzymes are loaded up with hydrogen and electrons that are used in the electron transport stage

KREB'S CYCLE STEPS

Involves preparatory steps:
- 3 carbon Pyruvate is converted into 2 carbon Acetyl-CoA
- NADH is formed from NAD^+ and electrons from the Pyruvate molecule
- CO_2 is produced by the addition of Coenzyme A
- Acetyl CoA (2 carbon) enters the cycle

1) Coenzyme A is removed and recycled
   - Resulting 2 carbon compound is attached to a 4 carbon Oxaloacetate
   - Forms a 6 carbon Citrate
2) Citrate has a water molecule removed
   - Forming 6 carbon Isocitrate
3) Electrons and hydrogens are given up to form an NADH molecule and one CO_2 molecule
   - Forms a 5 carbon alpha-Ketoglutarate
4) Electrons and hydrogens are removed from a ketoglutarate forming an NADH and one CO_2
5) Coenzyme A is added to the intermediate forming a 4 carbon Succinyl CoA
6) Coenzyme A and a phosphate are stripped from the Succinyl CoA
   - Forms a molecule of ATP and recycles the Coenzyme A
   - Results in the formation of a 4 carbon Succinate molecule
7) FAD removes hydrogens and electrons to form $FADH_2$
   - Results in the formation of a 4 carbon Fumarate molecule
8) Water is removed from Fumarate to form Malate
9) Electrons and hydrogens are removed to form the 4 carbon Oxaloacetae and one NADH molecule
   - Oxaloacetate is now available to pick up another pyruvate

ELECTRON TRANSPORT PHOSPHORYLATION

ATP production is the primary action
Produces about 32 ATP units from 1 glucose
This process occurs in the mitochondria
- Cristae define an inner compartment and an outer compartment

Mitochondrial membrane protein complexes transport electrons from high energy levels to lower energy levels
This releases energy which can be used to power proton (H^+) pumps
The electrons are derived from the NADH and $FADH_2$ molecules
The release of electrons from the NADH and $FADH_2$ molecules also releases H^+ ions into the inner compartments
H^+ ions are carried to the outer compartment of the mitochondria
- this sets up an H^+ concentration gradient as well as an electrical gradient

flow of H^+ ions back to the inner compartments of the mitochondria drive the formation of ATP
Oxygen withdraws electrons from the transport system and combines with H^+ to form water

ANAEROBIC RESPIRATION

do not use oxygen as the final electron acceptor
1) Fermentation
   a) Lactate fermentation
   b) Alcoholic fermentation
2) Anaerobic electron transport

FERMENTATION

energy is derived only from glycolysis steps in which 2 ATP are formed
final steps serve only to regenerate NAD^+
many bacteria and protists which live in oxygen poor settings perform this type of respiration
- bogs, mud, animal gut, sewage treatment ponds
- food spoilage, yogurt, sauerkraut, intense brief muscle contraction

End product is Lactic acid

ALCOHOLIC FERMENTATION

End product is ethanol (alcohol)
Enzymes differences produce acetaldehyde and CO_2
- Recycling of NAD^+ produces ethanol
- Performed primarily by bacteria and yeast in:
  - ethanol, bread, beer and wine production

ANAEROBIC ELECTRON TRANSPORT

Electrons and hydrogens are stripped from organic sources
same as fermentation and glycolysis
Alternative pathway for electron transport (inorganic source)
Net energy yield is very small

ALTERNATIVE ENERGY SOURCES IN THE HUMAN BODY

ENERGY FROM CARBOHYDRATES

Liver glycogen stores last about 12 hours
Sustained exercise and between meals
Fatty acid conversions supply 50% of ATP
Excess carbohydrates are converted to fats

GENETIC FACTORS OF CARBOHYDRATE CONVERSIONS

Genetic factors in 75% of individuals keep insulin levels elevated
Elevated insulin levels promote adipose cells to store fat rather than convert it for energy
25% of population have a genetic makeup which keeps insulin levels low
Low insulin levels promote conversion of fats to glucose by adipose cells and liver cells
Humans may be born with a genetic "set point" for body fat
Experiments beginning in 1950 with obese mice have led scientists to theorize that there may be an "obese" gene
1950 – an extremely obese mouse is discovered in the lab
Through crossbreeding a strain of obese mutant mice is developed
1994 – a mutated gene (ob) is discovered which produces a hormone called leptin
Hormone which influences the brain's commands to suppress appetite and increase metabolic rates
1995 – genetically engineered bacteria produce leptin which when injected into normal or obese mice triggers a significant weight loss
Without any apparent harmful side effects

ENERGY FROM FATS

Fatty acids have many more hydrogens available for uptake by NAD^+
Thus able to yield much more ATP energy than glucose

ENERGY FROM PROTEINS

enzymes split proteins into amino acid units
then remove the amino group (NH_3)
leaving a carbon backbone and an amino group
amino groups are converted to:
intermediates that produce urea (N_2 wastes)
urea is excreted as urine

END
Energy Pathways

A&P 1
Mitosis

CELL DIVISION

the process of cell division is essential to the growth and development of all organisms
growth and tissue repair are common occurrences
abnormal cell division is commonly called cancer

DNA REPLICATION

parent cells must provide daughter cells with hereditary instructions and enough cytoplasmic machinery to start up with their own operation
cells divide DNA by:
1) Mitosis

occurs in somatic cells

2) Meiosis

occurs in germ cells

CHROMOSOMES

Chromosomes are the genetic material found inside the nucleus of the cell
Consist of condensed DNA and proteins
DNA controls protein synthesis

Controls the appearance of characters and metabolic activities of an organism
chromosomes are condensed DNA molecules
while in a threadlike form chromosomes undergo duplication
each duplicated strand is called a sister chromatid
duplicated chromosomes narrow to a small region called the centromere
Each species has a fixed number of chromosomes in the nucleus of each of its cells
Chromosomes always exist in pairs in the body cells

SOMATIC CELLS

somatic cells in each species of organism will have the same number of chromosomes specific to that species
ex: humans = 46 gorillas = 48 pea plant = 14

DIPLOID

cells which have two of every chromosome are said to be diploid
ex: humans = 23 pair
ex: gorillas = 24 pair
diploid cell produces two identical diploid daughter cells
enables the chromosome number to remain constant generation after generation
cells function properly only if they receive one of each of the 23 different chromosomes

CELL CYCLE

Mitosis M
Gap phase 1 G_1
Synthesis phase S
Gap phase 2 G_2

M (mitosis)
nuclear division
cytoplasmic division
G_1 (gap 1)
interval before the onset of DNA replication
S (synthesis)
replication of DNA
G_2 (gap 2)
interval between completion of DNA replication and the onset of mitosis

INTERPHASE

usually the longest phase of the cell cycle
consists of the G1,S, and G2 phases of the cell cycle
1) the cell increases in mass
2) chromosomes cannot be seen
3) chromosomes are duplicated

STAGES OF MITOSIS

Prophase
Metaphase
Anaphase
Telophase

PROPHASE

1) chromosomes start condensing
chromatids twist and fold on one another
2) spindle fibers begin to form
3) centrioles are duplicated and begin to migrate to opposite poles
centrioles later give rise to cilia and flagella

METAPHASE

1) nuclear membrane disappears
2) spindle fibers attach to chromosome centromeres
3) spindle fibers from opposite poles “pull” on the chromosomes orientating them at the equator
4) chromosomes become aligned at the cell equator

ANAPHASE

1) the two sister chromatids of each chromosome are separated
2) chromatids move to opposite poles

TELOPHASE

1) the daughter chromosomes arrive at opposite poles
2) chromosomes begin to unwind and decondense to a threadlike DNA molecule
3) nuclear membranes form, enclosing the DNA
4) each new daughter cell has the same number of chromosomes as the parent cell

DIVISION OF THE CYTOPLASM

the cytoplasm divides during Telophase
cytokinesis- cytoplasmic division
animal cells “pinch in two” by a process called cleavage
Abnormal cell division at this point can lead to physical deformities

END
Cell Division