SYLLABUS FOR ADVANCED PLACEMENT BIOLOGY

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The purpose of this syllabus is to provide a working copy to those teachers of the advanced placement biology course taught at the high school level. Reference materials used were the Texas Education Agency (TEA) approved Campbell text Biology and the College Board's, Advanced Placement Biology Laboratory Manual. The syllabus is divided into major topics with outlined notes and includes laboratory exercises as recommended by the College Board.

The AP biology course is intended to be equivalent to college biology. College freshman biology courses can differ among colleges and among teachers within the same college. This syllabus is intended to serve as an aid to AP teachers, to cover the topics and experiments as set out by the College Board, and to the high school student, the necessary material to successfully complete the AP examination while providing freshman biology equivalence.

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TABLE OF CONTENTS

THEMES IN BIOLOGY

1. Hierarchy of organization:

   atoms

   complex biological molecules

   subcellular organelles

   cells

   tissues

   organs

   organ systems

   complex organism

   population

   community

   ecosystem

   biome

   biosphere

2. Emergent properties - properties that emerge as a result of interactions between components

   Distinguishing "living" organisms from nonliving:

   Characteristics of life:

   a. order

   b. reproduction

   c. growth and development

   d. energy utilization

e. response to environment

f. homeostasis

g. adaptation

3. Cellular basis of life

- cell is organism's basic unit of structure and function
- all organisms are composed of cells
- cells come from preexisting cells

a. Contributors to cell theory:

Hooke

Leeuwenhoek

Schleiden & Schwann

b. Types of cells

prokaryotic

eukaryotic

4. Heritable information

- biological instructions are encoded in DNA
- DNA composed of 4 nucleotides whose linear sequence encodes information found on genes
- inheritance based on mechanism for copying DNA
- all forms of life use the same genetic code
- differences among organisms result from differences in nucleotide sequence

5. Feeling for organisms

-The study of life is enriched by greater understanding of the parts that make up the organisms of life.

6. Correlation between structure and function

- form fits function

7. Interaction of organisms with their environment

- both organism and environment are affected by interaction between them

- Ecosystem dynamics include two major processes:

1. nutrient cycling

2. energy flow

8. Unity in diversity

- unity through DNA, cell structure & function, metabolic pathways

- diversity in 5 million - 30 million species

- taxonomy from most to least inclusive:

Kingdom

Phylum

Class

Order

Family

Genus

Species

- 5 (or 6) Kingdom scheme:

Living Organisms

Prokaryotic

Eukaryotic

Kingdom
MONERA
(Archaea)

Archaea

Eubacteria

Unicellular

Multicellular

Kingdom
PROTISTA

Autotrophic

(photosynthetic)

Heterotrophic

Kingdom
PLANTAE

Absorptive

nutrition

Ingestive

nutrition

Kingdom

ANIMALIA

Kingdom

FUNGI

9. Evolution (the core theme)

- species change over time, adapt to environment

-phylogenetic tree - pictorial representation of the evolutionary history of organisms

- Charles Darwin's " Origin of Species" 1859:

1. decent with modification

2. natural selection

10. Scientific process

- process which outlines a series of steps used to answer questions
- is not a rigid procedure
- based on conviction that natural phenomena have natural causes
- requires evidence to logically solve problems
- Hypothetico-deductive method:

Involves -

1.asking a question and formulating a tentative answer or hypothesis by inductive reasoning

2. using deductive reasoning to make predictions from the hypothesis and then testing the validity of those predictions

Hypothesis - educated guess proposed as a tentative answer to a specific question or problem

Inductive reasoning - making an inference from a set of specific observations to reach a general conclusion

Deductive reasoning - making an inference from general premises to specific consequences, which logically follow if the premises are true (usually takes the if.... then form) (usually involves predicting experimental results expected if the hypothesis is true)

- Characteristics of useful hypothesis:

1. tentative explanations for observations
2. based upon available evidence

3. multiple whenever possible

4. must be testable

5. can be proved false but not confirmed with absolute certainty

- Scientific process includes controlled experiments

Control group - group in which all variables are held constant

- for comparison

- allows conclusions about the effect of experimental manipulation

- key element of good experimental design

Variable - condition of an experiment that is subject to change and that may influence an experiment's outcome

Experimental group - group in which one factor or treatment is varied

CHEMICAL BASIS OF LIFE

Matter

Element

- 92 naturally occurring
- C,O,H,N - make up 96% of living matter
- trace elements - make up remaining 4 % of the weight of the organism
- atomic structure determines behavour of an element

Atom Composition

Particle	*Charge*	*Mass*	*Location*
proton	+	1	nucleus
electron	-	0	shells
neutron	no charge	1	nucleus

$$^{23}_{11}\mathrm{Na}$$

23 — *atomic mass*

Na — *symbol*

11 — *atomic number*

-neutral atom has same number of protons as electrons

-atomic weight - weighted mean of the masses of an element's constituent isotopes

-different isotopes of the same element react chemically in the same way

-radioactive isotope - nucleus spontaneously decays emitting particles and energy

-has a fixed half-life (time for 50% of atoms to decay)

-used in geological dating, tracers in biochemical pathways, disease diagnosis, cancer treatment

-electrons are the only stable subatomic particles directly involved in chemical reactions

-have potential energy because of their position relative to the positively charged nucleus

Nucleus

1st 2nd 3rd

greater energy

-may move from one energy level to another, in the process they gain or loss energy

There is a natural tendency for matter to move to the lowest state of potential energy

Orbital - space where an electron will most likely be found 90% of the time

- s, p, d, f

- diagonal rule

-maximum # of electrons in a shell

Chemical properties of an atom depend upon the number of valence electrons

Octet rule - valence shell is complete when it contains 8 electrons (except H & He)

Atoms with same number of electrons in their valence shells exhibit similar properties

Valence - bonding capacity

C H O N

Compounds

Molecule

Chemical bonds - attraction that holds molecules together

1. ionic - transfer of electrons

ion - charged atom or molecule

- anion - negatively charged
- cation - positively charged

2. covalent - sharing of electrons

-single

-double

-triple

- nonpolar - equal sharing of electrons between atoms
- polar - unequal sharing of electrons between atoms

Electronegativity - atom's ability to attract and hold electrons

-the more electronegative an atom, the more strongly it attracts shared electrons

- electronegative scale :

O = 3.5

N = 3.0

S & C = 2.5

P & H = 2.1

-electronegativity difference between interacting atoms determines if electrons are shared equally, unequally, gained or lost

WATER

Water supports life

Living cells are 70 - 95 % water

Water covers about 3/4 of the earth

Properties of water:

- exists naturally in all three states of matter
- is a polar molecule
- cohesion - contributes to the upward water transport in plants
- surface tension - air/water interface stronger than most liquids, causes beading
- resist changes in temperature
- has a high heat of vaporization and cools surfaces as it evaporates, has high specific heat (due to H bonds, must absorb heat to break, release heat when they form)
- expands when it freezes (ice floats)
- is a versatile solvent

Solutions & pH:

Water is called the universal solvent

- due to water's polarity
- ionic compounds dissolve in water
- polar compounds in general, are water soluble
- nonpolar compounds are not water soluble

Solute concentration in aqueous solution molecular weight - sum of the weight of all atoms in a molecule

mole (mol) - equal in number to the molecular weight

molarity - number of moles of solute per liter solution

-procedure to determine molar (M) solutions

1. calculate molecular weight
2. measure out weight of substance in grams
3. add substance to solvent
4. fill to 1 liter

Water can dissociate

- only hydrogen ion (proton w/ +1 charge) is transferred
- transferred proton binds to another water molecule creating a hydronium ion
- water molecule that lost proton is hydroxide ion

Acid - produces hydrogen ions when placed in water solution

Base - produces hydroxide ions when placed in water solution

Strong acids and bases dissociate completely in water

Weak acids and bases dissociate only partially

pH scale - logarithmic scale that measures hydrogen ion concentration in a solution

0 1 2 3 4 6 7 8 9 10 11 12 13 14

acid neutral base

Buffers - substances consisting of H+ donor and H+ acceptor, forms of weak acids and bases

- minimize wide fluctuations in pH, will accept or donate H+ as needed

ORGANIC CHEMISTRY

Early 19th century organic chemistry built on foundation of vitalism, believed that only living organism could produce organic compounds

Mechanism - belief that all natural phenomena, including life processes, are governed by physical and chemical laws

- Wohler - 1828 synthesized urea
- Kolbe - synthesized acetic acid
- Miller - 1953 demonstrated that compounds could have been produced under chemical conditions of primordial earth (water, hydrogen, ammonia, and methane)

Organic chemistry - study of compounds containing carbon

Carbon

- atomic number of 6
- 4 valence electrons, forms 4 covalent bonds
- can form large complex molecules
- covalent compatibility with other 3 major atomic components of organic molecules (H, O, N)
- attributes to complexity and diversity of organic compounds through its variations in carbon skeletons
- length
- shape (straight chain, branched, ring)
- number and location of double bonds

- other elements covalently bonded to available sites

Hydrocarbons - organic molecules consisting of only hydrogen and carbon

- biologically important, component of lipids
- major component of fossil fuels
- chains are hydrophobic, C-C and C-H bonds are nonpolar

Isomers - compounds with same molecular formula but different structures

- structural differences mean different properties

1. structural - differ in covalent arrangement
2. geometric - same covalent partnership but differ in their spatial arrangement (double bonds prevent rotation, affects biological activity)
3. enantiomers - mirror images of each other (usually one form is biologically active & mirror image is not)

Functional groups - regions attached to carbon skeleton of organic molecules that are involved in chemical reactions and contribute to molecular diversity

- have specific chemical & physical properties
- are regions which are commonly chemically reactive
-behave consistently from one organic molecule to the other
- determine unique chemical properties of organic molecules in which they occur

1.hydroxyl group (alcohols) (- OH) - polar, makes molecule it's attached to water soluble

2.carbonyl group (aldehydes & ketones) (-C=O) - polar, water soluble, found in sugars

3.carboxyl group (carboxylic acids) (-COOH) - polar, water soluble, H+ reversibly dissociates, donation of protons (H+) gives it acidic properties

4.amino group (amines) ($-NH_2$) - polar, water soluble, acts as weak base due to picking up H+ from surroundings

5. sulfhydryl group (thiols) (-SH) - help stabilize the structure of proteins

6. phosphate group (dissociated form of phosphoric acid, H_3PO_4)

-has acidic properties, polar, water soluble, important in cellular energy storage and transfer

MACROMOLECULES

poly - many   mer - part   mono - one   macro - large

Macromolecules in living organisms are formed from 40 - 50 common monomers

Condensation reaction (dehydration synthesis) - covalent linking of monomers by removal of water molecule

- requires enregy
- requires enzymes

Hydrolysis - breaking covalent bonds in polymers by the addition of water molecule (H combines with one monomer, OH to other)

- requires enzymes
- produces monomers whose breakdown releases energy

Living organisms consist of 4 types of macromolecules:

1. Carbohydrates - organic molecules of C, H, O used for fuel & building material by cells, end in "ose"

   - classification based upon number of simple sugars:

   monosaccharides - simple sugars with C, H, O in fixed ratio of 1:2:1, major nutrients for cells

   - glucose most common
   - produced during photosynthesis from CO_2, H_2O, and sunlight
   - store energy in chemical bonds that can be harvested by cellular respiration
   - carbon skeletons are raw materials for other organic molecules
   - contain -OH group attached to C except one with carbonyl (C=O)

glucose - aldose fructose - ketose

- size of carbon skeleton varies from 3 - 7 C
- variation around asymmetrical carbons

galactose and glucose are enantiomers

affects molecular shape that results in distinctive biochemical properties

- in aqueous solutions, many monosaccharides form rings

disaccharides - two monosaccharides joined by a glycosidic linkage (covalent bond formed by condensation reaction between monomers)

polysaccharides - macromolecules that are polymers of monosaccharides

- energy storage (starch & glycogen)
- structural support (cellulose & chitin)

starch - glucose polymer that is storage polysaccharide in plants

- stored as granules within plant plastids
- most animals have digestive enzymes to hydrolyze starch
- source for human diet (potatoes & grains)

glycogen - glucose polymer that is storage polysaccharide in animals

- stored in muscle and liver cells

cellulose - structural polysaccharide

- major structural component of plant cell walls
- reinforces plant cell walls , H bonds hold together parallel cellulose molecules that form microfibrils
- cannot be digested by most organisms

chitin - structural polysaccharide that is a polymer of an amino sugar

- forms exoskeleton of arthropods

- building material in cell walls of some fungi

- monomer is an amino sugar (like glucose but contains N group replacing a hydroxyl)

2. Lipids - organic compounds that are insoluble in water

3 types:

1. fats - composed of glycerol (3C alcohol) joined by ester linkage to fatty acids (carboxylic acid)

ester linkage - bond formed between a hydroxyl and a carboxyl

triglyceride - fat composed of three fatty acids bonded to one glycerol by ester linkage

types of fats :

1. saturated - no double bonds between C

- solid at room temperature

- most animal fats

2. unsaturated - one or more double bonds between C

- liquid at room temperature

- most plant fats

function of fats:

- energy storage

- cushions vital organs

- insulates against heat loss

2. phospholipids - glycerol attached to two fatty acids and one phosphate group

- hydrophilic head (phosphate group), negative

- hydrophobic tail (hydrocarbon, fatty acid)

- droplets cluster in water forming micelle

- major component of cell membrane (spontaneously form bilayer in water)

3. steroids - lipids w/ 4 fused carbon rings w/ various functional groups attached

cholesterol - steroid that is precursor to many animal hormones, component of cell membranes

3. Proteins - macromolecules that consist of one or more polypeptide chains folded and coiled into specific conformations

- polypeptide chains - polymers or amino acids that are arranged in a specific linear sequence and are linked by peptide bonds

peptide bond - condensation reaction linking the carboxyl (OH) of one amino acid to the amino (H) of the next

- make up 50% or more of a cell's dry weight

- function in structural support

- " " storage of amino acids

- " " transport (hemoglobin)

- " " signaling (chemical messengers)

- " " cellular response (receptor proteins)

- " " movement (contractile proteins)

- " " defense (antibodies)

- " " catalyst (enzymes)

- vary in structure, each with unique conformation

- are commonly made of only 20 amino acid monomers

amino acids - monomers of proteins, most of an asymmetrical carbon that is covalently

bonded to:

1. hydrogen atom

2. carboxyl group

3. amino group

4. R group - whose physical & chemical properties determine the uniqueness of the amino acid

H H O

N C C

H OH

R

amino = base carboxyl = acid

- 20 amino acids can be grouped by properties of their R group

1. nonpolar - hydrophobic

2. polar - hydrophilic

3. acidic - negative charge

4. basic - positive charge

Protein's function depends upon its conformation

Primary - sequence of amino acids, determined by genes

Secondary - repeated coiling & folding

- alpha helix - H bonding between every 4th amino acid (keratin & collagen)

- beta pleated sheet - parallel amino groups linked by H bonding (fibroin)

Tertiary - interactions between side chains

- H bonding between polar side chains

- ionic bonds between charged side chains

- hydrophobic interactions between nonpolar side chains, (results in clusters)

- disulfide bridges - between R group containing sulfhydrl group (-SH) that link S - S covalently

Quaternary - structural arrangement due to more than one polypeptide chain (collagen, hemoglobin)

- conformation influenced by environmental conditions

- denaturation - process that alters a protein's native conformation & biological activity, occurs through:

1. excessive heat

2. chemical agents

3. transfer to organic solvent

- can reform if conditions return to normal

4. Nucleic acids - macromolecules composed of nucleotides that store and transmit hereditary information

2 types:

1. DNA (deoxyribonucleic acid)

- contains coded information that programs a cell's activity

- contains directions for its own replication

- is copied & passed from one generation of cells to another

- found primarily in nucleus of eukaryotes

- makes up genes that direct mRNA synthesis

- double helix structure consisting of 2 strands of nucleotides held together by H bonds between bases

- two strands are complements of one another

A pairs with T C pairs with G

- sequence comparisons show evolutionary relationships between species

2. RNA (ribonucleic acid)

- functions in actual synthesis of proteins

gene - segment of DNA

nucleotides - monomer units of nucleic acids, composed of a 5 - C sugar, phosphate, and a nitrogenous base

5 - carbon sugar - DNA=deoxyribose RNA= ribose

phosphate - attached to number 5 carbon of sugar

nitrogenous bases divided into 2 groups:

1. Purines - five-membered ring fused to six-membered ring

Adenine (A) Guanine (G)

2. Pyrimidines - six-membered ring of C & N

Cytosine (C) Thymine (T) Uracil (U)

(DNA only) (RNA only)

- nucleotides joined by phosphodiester linkage between phosphate of one and sugar of next forming backbone with bases attached to sugars

METABOLISM

Metabolism- totality of an organism's chemical properties

Metabolic reactions are organized into pathways that are orderly series of enzymatically controlled reactions

-two types of metabolic pathways

1.catabolic - pathways that release energy by breaking down complex molecules to simpler compounds

2.anabolic - pathways that consume energy to build complex molecules from simpler ones

-metabolic reactions may be coupled - energy from a catabolic reaction can be used to drive an anabolic one

Energy - capacity to do work

- kinetic energy - energy in the process of doing work (energy in motion)

-potential energy - energy that matter possesses because of its location or arrangement (energy of position)

Chemical energy is potential energy stored in molecules because of the arrangement of nuclei and electrons in its atoms

Two Laws of Thermodynamics:

1st Law - Energy can be transferred and transformed, but cannot be created or destroyed

2nd Law - Every energy transfer or transformation makes the universe more disorderly (every process increases the entropy of the universe)

Thermodynamics - study of energy transformations

-closed system - collection of matter under study which is isolated from its surroundings

-open system - system in which energy can be transferred between the system and its surroundings

The quantity of energy in the universe is constant , but its quality is not

Entropy - Quantitative measure of disorder that is proportional to randomness

Organisms live at the expense of free energy

Free energy - portion of a system's energy available to do work; criterion for spontaneous change

$$G = H - TS$$

G= free energy

H = total energy

T = temperature in K

S = entropy

Spontaneous reaction - reaction that occurs w/o the addition of energy

- ^ G of a system decreases (- ^ G)

  - temperature is a contributing factor

  - decrease ^H and an increase in ^S contributes to spontaneity by reducing G

High energy chemical systems are unstable and tend to change to a more stable state with a lower free energy

As a reaction approaches equilibrium, the free energy of the system decreases

- at equilibrium ^G = 0

- system can do no work

Chemical reactions in metabolism can be either:

- exergonic - net release of energy (spontaneous) (-^G)

- endergonic - absorbs energy (nonspontaneous) (+^G)

Metabolic disequilibrium is essential to life

ATP (adenosine triphosphate) - nucleotide with unstable phosphate bonds that the cell hydrolyzes for energy to drive endergonic reactions

- composed of adenine - nitrogenous base

ribose - 5 carbon sugar

chain of 3 phosphate groups

- unstable bonds of phosphate groups can be hydrolyzed in an exergonic reaction that releases energy (unstable due to all P being negative)

$$ATP + H_2O \qquad ADP + P_i$$

- transfer of phosphate group to another molecule

- is enzymatically controlled

ATP powers cellular work by coupling exergonic to endergonic reactions.

Phosphorylated intermediate - recipient of P - forms a more reactive molecule than original

Regeneration of ATP

$$ADP + P_i \qquad ATP$$

- endergonic reaction whose energy comes from cellular respiration

Enzymes speed up and control the rates of biochemical reactions enzyme - biological catalyst, usually proteins

catalyst - chemical agent that changes the rate of a chemical reaction without being consumed or altered

Free energy of activation (activation energy - EA) - amount of energy that reactant molecules must absorb to start a reaction

Transition state - unstable condition of reactant molecules that have absorbed sufficient free energy to react

Enzymes do not change ^G of a reaction

Enzymes are substrate specific and that specificity depends upon the enzyme's three – dimensional shape (conformation)

Substrate - the reactant an enzyme acts upon

Active site - restricted region of an enzyme molecule which binds to the substrate

- usually a pocket or groove on protein's surface
- formed with only a few enzyme's amino acids
- determines enzyme's specificity
- substrate induces the enzyme to change shape
- brings enzyme's chemical groups into position that enhances ability to interact w/ substrate and catalyze the reaction

Induced fit - change in the shape of an enzyme's active site, which is induced by the substrate

Enzymes lower EA and speed up reactions by :

1. holding reactants in proper position for reaction

2. distorting substrate's chemical bonds

3. providing micro - environment conducive to reaction

4. side chains in active site participating directly

Initial substrate concentration partly determines the rate of an enzyme controlled reaction

- higher substrate concentration, faster the reaction (to a point)

- if substrate concentration is high enough, the enzyme becomes saturated with substrate

-if enzyme is saturated, the reaction rate depends upon how fast the active site can convert substrate to product

- reaction rate may be increased by adding more enzyme

A cell's chemical and physical environment affects enzyme activity

- temperature - as a rule enzyme reaction rate increases with increasing temperature (increased collision between substrate and active site)

- optimal temperature range of most human enzymes is 35 - 40 C

- extreme temperature denatures enzyme

- pH - optimal range for most human enzymes is between 6 - 8

Cofactors - small nonprotein molecules required for proper enzyme catalysis

- may bind tightly to active site

- may bind loosely to both active site & substrate

- some inorganic (metals - zinc, iron, copper)

- coenzymes - organic (vitamins)

Enzyme inhibitors - chemicals that selectively inhibit enzyme activity

- irreversible - inhibitor attaches covalently
- reversible - inhibitor attaches by weak bonds

Competitive inhibitors - resemble an enzyme's normal substrate & compete for active sites

- block active site from substrate

Noncompetitive inhibitors - do not enter active site, bind to another part of the enzyme molecule

- enzyme changes shape so substrate can't bind
- may act as metabolic poison (DDT, antibiotics)

Selective enzyme inhibition is essential for regulating metabolic reactions.

Allosteric site - specific receptor site on some part of enzyme other than active site

- most have 2 or more polypeptide chains, sites often located where subunits join
- allosteric enzymes have 2 conformations

  catalytically active & inactive
- binding of activator stabilizes active conformation
- binding of inhibitor stabilizes inactive conformation

Enzyme activity changes continually in response to changes in the relative proportions of activators and inhibitors (ATP, ADP)

Subunits of allosteric enzymes may interact

- single activator or inhibitor at one site will affect active sites of other subunits

Cooperativity - substrate binding to the active site of one subunit enhances binding at active sites of other subunits

Metabolic pathways are regulated by controlling enzyme activity

Feedback inhibition - regulation of a metabolic pathway by its end product, which inhibits an enzyme within the pathway

CELL STRUCTURE

Invention of the microscope led to advancements in biology

Magnification - how much larger an object is made to appear compared to its real size.

total magnification = ocular x objective lens

Resolving power - minimum distance between two points that can still be distinguished

inversely related to the wavelength of light or radiation a microscope uses

Types of microscopes:

1. Light microscope (LM) - uses visible light passing through specimen and magnifies image with objective and ocular lens
   - -1000X magnification
   - -0.2 micrometer resolution
   - -used to observe live specimens

2. Electron microscope (EM) - beam of electrons focused on specimen, image magnified by objective and projector lens
   - -0.2 nanometer resolution
   - -specimen must be killed and stained

   a. transmission electron microscope (TEM) - used to study internal cellular structure

   b. scanning electron microscope (SEM) - gives a 3 dimensional view of surface

Most cells are between 1 and 100 micrometers in diameter

1 micrometer = 1/1000 mm   1 nm = 1/1000 micrometer

Cell fractionation - technique which involves centrifuging disrupted cells at various speeds and durations to isolate components of different sizes, densities and shapes

- steps involved:
  1. homogenization - disruption of cells
  2. centrifugation of homogenate to produce pellet
  3. supernatant centrifuged at high speed to pellet
  4. supernatant centrifuged at higher speed

-centrifugation at increasing speeds and durations produce pellets containing smaller components

Cells divided into two types:

Prokaryotic - Found only in Monerans (bacteria)

Eukaryotic - Members of kingdoms Protista, Fungi, Plantae, and Animalia

- true nucleus containing genetic material
- membrane bound organelles

Cell size - limited by surface area to volume ratio

Cell structure:

cytoplasm - region between nucleus and cell membrane

cytosol - semi-fluid medium of cytoplasm

plasma membrane - phospholipid bilayer surrounding cell that is selectively semipermeable and controls passage of molecules in and out of cell

-eukaryotes have compartmental organization through internal membranes that:

a. partition the cell creating localized environmental conditions necessary for specific metabolic processes

b. have unique lipid and protein compositions depending upon specific function

c. may participate in metabolic reactions since many enzymes are incorporated directly into the membrane

d. sequester reactions so they may occur without interference from incompatible metabolic processes elsewhere in the cell

Nucleus - membrane bound organelle that contains most of the genes that control the cell

- surrounded by nuclear membrane (double membrane containing nuclear pores that regulate molecular traffic in and out of nucleus)
- nuclear lamina - network of protein filaments on nuclear side of membrane that stabilizes nuclear shape
- chromatin - DNA and proteins that make up chromosomes
- chromosomes - long threadlike association of genes formed from chromatin
- nucleolus - spherical region of nucleus involved in the synthesis of ribosomes

Ribosome - cytoplasmic organelle that synthesizes proteins

- complexes of RNA and protein
- constructed in nucleolus
- either free or bound to E.R.
  - free- suspended in cytosol
  - bound - attached to outside of E.R.

Protein synthesis is performed in cytoplasm, controlled by nucleus:

- mRNA transcribed in nucleus from DNA instructions
- mRNA passes through nuclear pores into cytoplasm
- mRNA attaches to ribosomes where message is translated into protein

- proteins made by free ribosomes function in cytosol
- proteins made by ribosomes generally destined for membrane inclusion, packaged within organelles, or export out of cell

Biologists now consider many membranes of the eukaryotic cell to be part of an endo-membrane system

- membranes may be interrelated directly through physical contact
- membranes may be related indirectly through vesicles
- Endomembrane system includes:
  - nuclear membrane
  - endoplasmic reticulum
  - Golgi apparatus
  - lysosomes
  - vacuoles
  - plasma membrane (related)
- membranes vary in structure and function, are dynamic structures themselves changing in composition, thickness and behavior

Vesicles - membrane-enclosed sacs from pinched off portions of membrane that travel from one membrane to another

Endoplasmic reticulum (E.R.) - extensive membraneous network of tubules and sacs (cisternae) which sequesters its internal area (cisternal space) from the cytosol

- continuous with the outer membrane of the nuclear envelope (space between the membranes of nuclear envelope is continuous with cisternal space)

- 2 distinct regions of E.R. with different structure and function:

1. smooth E.R. - cytoplasmic surface lacks ribosomes

- synthesizes lipids, phospholipids, and steroids

- participates in carbohydrate metabolism

- detoxifies drugs and poisons

- stores calcium ions necessary for muscle contractions

2. rough E.R. - cytoplasmic side studded with ribosomes

- is continuous with outer membrane of nuclear membrane

- manufactures secretory proteins and membrane

Golgi apparatus - organelle made of stacked, flattened membranous sacs (cisternae), that modifies, stores and routes products of the E.R

- has distinct polarity

cis face - receives transport vesicles from E.R. (vesicle membrane fuses with cis face and empties soluble contents in Golgi's cisternal space)

trans face - pinches off vesicles from the Golgi and transports molecules to other sites

- enzymes in the Golgi modify products of the E.R. in stages as they move through the Golgi stack from cis to trans face

-sorts products for secretion, products leave the trans face in vesicles which eventually fuse with plasma membrane

Lysosome - An organelle which is a membrane-enclosed bag of hydrolytic enzymes that digest all major classes of macromolecules

- functions include:

intracellular digestion

recycle cell's own organic material

carry out programmed cell destruction

Vacuole - membrane bound organelle, larger than vesicle with various functions:

- food vacuole - form food storage units
- contractile vacuole - expel excess water
- central vacuole of plant cell

Peroxisomes - membrane bound organelles that contain specialized teams of enzymes for specific metabolic pathways

- contain peroxide-producing oxidases that transfer hydrogen from various substrates to oxygen, producing hydrogen peroxide
- bound by single membrane

Mitochondria - organelles which are the sites of cellular respiration

Plastids - plant and algal organelles that include amyloplasts, chromoplasts, and chloroplasts

Cytoskeleton - a network of fibers throughout the cytoplasm that forms a dynamic framework for support and movement

- gives mechanical support and helps maintain shape
- enables cell to change shape
- associated with motility by interacting with specialized proteins called motor molecules
- constructed of at least 3 types of fibers:

1. microtubules - found in cytoplasm of all eukaryotic cells

straight hollow fibers about 25 nm in diameter & 200nm - 25 micrometers in length

constructed from globular proteins called tubulin

elongate by adding tubulin units to its ends

may be dissembled and tubulin units recycled to build microtubules elsewhere

function in cellular support, provide tracks for organelle movement, separation of chromosomes during cell division, make up centrioles in animal cells

Cilia and flagella - locomotor organelles found in eukaryotes which are formed from a specialized arrangement of microtubules

- may propel single-celled organisms
- may function to draw fluid across the surface of stationary cells

structure:

are extentions of plasma membrane

spokes radiate out from center that connect 9 doublets to 2 core

dynein (protein motor molecule) attaches neighboring doublets, a conformational change powered by ATP in dynein results in bending of microtubules that causes undulating motion of flagella or beating in cilia

basal body - anchoring structure at base of cilia or flagella, 9-3

2.microfilaments (actin filaments) - solid rods about 7 nm in diameter that aid in movement

- built from globular protein monomers linked together into long chains, two chains wound together to form helix

functions:

participate in muscle contraction

provide cellular support

responsible for localized contraction of cells -

pinching in two of dividing animal cells

amoeboid movement

cytoplasmic streaming of plant cells

3. intermediate filaments:

8 - 12 nm in diameter

differ in diameter and composition depending on cell type

constructed from keratin

more permanent than microfilaments and microtubules

function:

framework for the cytoskeleton

reinforce cell shape

probably fix organelle position

compose the nuclear lamina

Cell wall - external coat of plant cells

- strong cellulose fibers embedded in matrix of other polysaccharides and proteins

- function to protect plant cell, maintain shape, and prevent excess water uptake

- has plasmodesmata that connect cytoplasm of neighboring cells

Plant cell development:

1. primary cell wall

2. middle lamella of pectin (sticky polysaccharide)

3. secondary cell wall

Extracellular matrix (ECM) - meshwork of macromolecules outside the plasma membrane of animal cells

- locally secreted by cells
- composed mostly of glycoproteins (collagen)
- functions in support, to anchor the cell, and helps control gene activity in cell's nucleus

Intercellular junctions:

Plants - plasmodesmata - membrane bound channels that connect adjacent cells allowing movement throughout

Animals -

Tight junctions - intercellular junctions that hold cells together tightly enough to block transport

Desmosomes - intercellular junctions that rivet cells together into strong sheets, but still permit substances to pass freely through intercellular space

Gap junctions - intercellular junctions specialized for material transport between the cytoplasm of adjacent cells

MEMBRANE STRUCTURE AND FUNCTION

Plasma membrane - boundary that separates living cell from its nonliving environment

- 8 nm thick

-controls chemical traffic into and out of cell

-selectively permeable

-unique structure that determines function and solubility characteristics

structure:

phospholipid bilayer with embedded proteins and surface carbohydrates

Evolution of membrane models:

1. 1935 - Davidson and Danielli proposed sandwich model - phospholipid bilayer between two layers of globular proteins

   Problems:

   1. not all membranes were alike

   2. membrane proteins are amphipatic (have hydrophilic and hydrphobic regions)

2. 1972 - Singer and Nicholson proposed that proteins were spaced within fluid phospholipid bilayer with their hydrophilic regions protruding far enough from the bilayer to be exposed to water

Fluid Mosiac Model - currently accepted

-held together by hydrophobic interacytions

-most lipids and some proteins can drift about literally in the plane of the membrane (witnessed by Frye and Edidin experiment of fusing human cell with mouse cell, each labeled with dye, after one hour proteins intermixed)

-some membrane proteins are tethered to cytoskeleton and can't move

-fluidity can change resulting in permeability changes and enzyme deactivation

unsaturated hydrocarbon tails enhance fluidity with kinks at the C - C double bond hinder packing of phospholipids

membranes can solidify at decreased temperature (plants adjust by increasing the unsaturated phospholipid concentration)

cholesterol in eukaryotic membranes restrain phospholipid movement at warmer temperature and prevent close packing at cooler temperature

-mosiac structure due to embedded and dispersed proteins that occur in two spatial arrangements:

1. Integral proteins - inserted such that their hydrophobic regions are surrounded by hydrocarbon portions of phospholipids

   -can be unilateral - reaching only partway across membrane

   -can be transmembrane - with hydrophobic midsections between hydrophilic ends exposed on both sides of the membrane

2. Peripheral proteins - not embedded, but attached to membrane's surface

   -can be attached to integral proteins or held by fibers of ECM

   -on cytoplasmic side, may be held by filaments of cytoskeleton

-membranes are bifacial - membrane's synthesis and modification by Golgi determines this asymmetric distribution of lipids, proteins and carbohydrates:

two lipid layers may differ in lipid composition membrane proteins have distinct directional orientation

when present, carbohydrates are restricted to membrane's exterior

side of membrane facing lumen of E.R., Golgi, and vesicles is topologically the same as the plasma membrane's outside face

side of the membrane facing the cytoplasm has always faced the cytoplasm, from inception to fusion with plasma membrane

Cell-to-cell recognition - the ability of a cell to determine if other cells it encounters are alike or different from itself

- crucial in functioning of organisms:

  1. sorting of animal embryo's cells into tissues and organs

  2. rejection of foreign cells by immune system

-cells recognize other cells by markers (most carbohydrates)on surface of plasma membrane

usually branched oligosaccharides

some glycolipids

most glycoproteins

markers vary from species to species, between individuals of same species, and among cells of same individual

Selective permeability - property of biological membranes which allows some substances to cross more easily than others

-depends upon solubility characteristics of phospholipid bilayer and presence of specific integral transport proteins

Rate of transport differs:

1. nonpolar (hydrophobic) molecules

-dissolve in membrane and cross easily (O and hydrocarbons)

-smaller molecules cross faster

2. polar (hydrophilic) molecules

-small uncharged molecules pass easily (water and carbon dioxide)

-larger, polar charged molecules will not easily pass through (glucose)

-all ions have difficulty (sodium, hydrogen)

Transport proteins - integral membrane proteins that transport specific molecules or ions across biological membranes

-can provide hydrophilic tunnel through membrane

-can bind to substance and carry it across membrane

-are specific for the substance they translocate

Diffusion - the net movement of a substance down a concentration gradient

-results from the intrinsic kinetic energy of molecules and random molecular motion

-continues until a dynamic equilibrium is reached

- in the absence of other forces , a substance will diffuse from high to low concentration

-decreases free energy, is spontaneous

-increases entropy of system by producing more random mixture of molecules

-a substance diffuses down its own concentration gradient and is not affected by gradients of other substances

Passive transport - diffusion of a substance across a biological membrane without the use of energy

-spontaneous, a function of concentration gradient

-potential energy stored in concentration gradient drives diffusion

- rate of diffusion regulated by permeability of membrane

-water diffuses freely across most cell membranes

Hypertonic solution - a solution with a greater solute concentration than that inside the cell

Hypotonic solution - a solution with a lower solute concentration compared to that inside inside the cell

Isotonic solution - a solution with an equal solute concentration compared to that inside a cell

Osmosis - diffusion of water across a selectively permeable membrane

-water diffuses down its concentration gradient

-some solute molecules that are hydrophilic can reduce the proportion of water molecules that can freely diffuse (water becomes bound to solute)

-in most biological fluids it is the difference in the proportion of unbound water that causes osmosis, rather than the actual difference in water concentration

-direction of osmosis is determined by the difference in <u>total</u> solute concentration, regardless of the type or diversity of solutes in the solutions

-in an isotonic solution, water diffuses across membrane equally in both directions. There is no net movement of water.

Osmotic concentration - total solute concentration of a solution

Osmotic pressure - measure of the tendency for a solution to take up water when separated from pure water by a selectively permeable membrane

-osmotic pressure of pure water is zero

-osmotic pressure of a solution is proportional to its osmotic concentration (the greater the solute concentration, the greater the osmotic pressure)

Osmoregulation - the control of water balance

-differs in cells with and without cell walls

-contractile vacuole - specialized organelle for the removal of excess water

-animal cells bathed in isotonic solutions

-plant cells have cell walls

Plasmolysis - phenomenon in walled cells in which the cytoplasm shrivels and the plasma membrane pulls away from the cell wall when cell placed in a hypertonic solution

Facilitated diffusion - diffusion of solutes across a membrane with the help of transport proteins

-is passive, down solute's concentration gradient

-helps the diffusion of many polar molecules and ions

Transport proteins

-are specific for solutes they transport

-can be saturated, maximum transport rate

-can be inhibited by molecules that resemble solute normally carried across

-can change conformation allowing solute molecules entry

-can act as gated channels (open in response to stimuli)

Active transport - energy-requiring process during which a transport protein pumps a molecule across a membrane <u>against</u> its concentration gradient

-is energetically uphill, requires cell to expend energy

-helps cells maintain steep ionic gradients across cell membrane

-transport proteins harness energy from ATP to pump molecules against their concentration gradient sodium - potassium pump:

1. transport protein oscillates between two conformations -

   a. high affinity for sodium with binding sites oriented towards the cytoplasm

   b. high affinity for potassium with binding sites oriented towards cell's exterior

2. ATP phophorylates the transport protein and powers the conformational change from sodium receptive to potassium receptive

3. as transport protein changes conformation, it translocates bound solutes across the membrane

4. sodium - potassium pump translocates 3 sodium ions out of cell for every 2 potassium ions pumped into cell

Membrane potential - voltage across membrane

-ranges from -50 to -200 mv, cell's inside is negative with respect to outside

-affects traffic of charged substances across membrane

-favors diffusion of cations into cell and anions out of cell

-factors contributing to a cell's membrane potential:

   1. negatively charged proteins in cell's interior

   2. plasma membrane's selective permeability to various ions

   3. sodium - potassium pump - loss of one positive charge per cycle

Two forces drive passive transport of ions across membrane:

1. concentration gradient of the ion

2. effect of membrane potential on the ion

Electrochemical gradient - diffusion gradient resulting from the combined effects of membrane potential and concentration gradient

-ions may not always diffuse down their concentration gradients, but will always diffuse down their electrochemical gradients

-at equilibrium, distribution of ions on either side of membrane may be different from expected due to charge

-uncharged solutes unaffected by membrane potential

Electrogenic pump - a transport protein that generates voltage across a membrane

-sodium - potassium ATPase is the major electrogenic pump in animal cells

-proton pump is major electrogenic pump in plants, bacterial and fungal cells. Found in mitochodria and chloroplast, used to drive ATP synthesis.

-voltages created by electrogenic pumps are sources of potential energy available to do cellular work

Cotransport - process where a single ATP-powered pump actively transports one solute and indirectly drives the transport of other solutes against their concentration gradients

-plants use H+ proton pump coupled with sucrose H+

Water and small molecules cross membrane by passing through phospholipid bilayer or being translocated by transport proteins

Large molecules (proteins and polysaccharides) cross membrane by process of exocytosis and endocytosis

Exocytosis - process of exporting macromolecules from the cell by fusion of vesicles with the plasma membrane

-vesicle usually budded from E.R. or Golgi and migrates to plasma membrane

-used by secretory cells to export products (insulin in pancreas, neurotransmitter from neuron)

Endocytosis - process of importing macromolecules into a cell by forming vesicles derived from the plasma membrane

3 types of endocytosis:

1. phagocytosis "cell eating" - endocytosis of solid particles

-engulfs particle with pseudopodia and pinches off food vacuole

-vacuole fuses with lysosome containing hydrolic enzymes

2. pinocytosis "cell drinking" - endocytosis of fluid droplets

-droplets of extracellular fluid taken into small vesicles

-nondiscriminating, takes in all solutes within droplets

3. receptor-mediated endocytosis - process of importing specific macromolecules into the cell by the inward budding of vesicles

-regions of membrane exposed to cell's exterior that contain embedded proteins that act as specific receptor sites (proteins cluster to form coated pits)

-ligand - molecule that binds to a specific receptor site (example - cholesterol)

In a nongrowing cell, the amount of plasma membrane remains relatively constant, endocytosis offsets exocytosis

Specialized membrane proteins transmit extracellular signals to the inside of the cell

Integrins - specific integral proteins that transmit physical stimuli from the extracellular matrix to the cytoskeleton inside and influence cell shape and movement

-can transduce chemical signals from the outside

Signal-transduction pathway - chain of molecular interactions that lead to various responses within the cell:

1. extracellular molecule (first messenger) binds to membrane's receptor protein

2. receptor protein activates a relay protein in the membrane

3. relay protein stimulates another membrane protein (effector), an enzyme which causes changes within the cell

4. the effector catalyzes the production of a cytoplasmic molecule (second messenger)

5. second messenger triggers metabolic and structural responses within the cell

-example - hormone epinephrine (1st messenger) binds to receptor in plasma membrane of liver cell, relay protein, effector, hydrolzes glycogen, glucose cellular work

CELLULAR RESPIRATION

Metabolism - totality of an organism's chemical processes

-anabolic pathways - consume energy to build complex molecules (photosynthesis)

-catabolic pathways - release stored energy by breaking down complex molecules (cellular respiration and fermentation)

Cellular respiration:

$C_6H_{12}O_6 + 6O_2$ --------------------------> $6CO_2 + 6H_2O$ + energy (ATP & heat)

-exergonic (releases energy), 686 kcal/mol

ATP - central character in bioenergetic (study of how organisms manage their energy resources)

-structure of ATP

-loss of one P releases 13kcal/mol

-relocation of electrons releases energy stored in organic compounds

Oxidation - loss of e- or H atom, releases energy

Reduction - gaining of e- or H atom, requires energy

Redox reaction (oxidation-reduction reaction) - oxidation and reduction occurring together:

oxidation

$Na + Cl$ --------------> $Na^{+} + Cl^{-}$

reduction

-reducing agent - electron donor (Na)

-oxidizing agent - electron acceptor (Cl)

Some redox reactions just change degree of sharing in covalent bonds:

oxidation

CH_4 + $2O_2$ ------------------------------> CO_2 + $2H_2O$ + energy

----
reduction

Electronegativity - attraction for e-s

-oxygen - high electronegativity = potent oxidizing agent

-when moving from less electronegative to more electronegative atom, e- loses energy

oxidation

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

----
reduction

In respiration H is transferred from glucose (oxidation) to oxygen (reduction) producing energy

-energy released is used to produce ATP

-H is not transferred directly to O_2, but follows path -

glucose (food) ----- NADH + H+ ----- E.T.S. ----- oxygen

NAD+ (nicotinamide adenine dinucleotide) - coenzyme found in all cells, accepts H and/or e- during respiration; acts as oxidizing agent

Dehydrogenases - enzymes that remove 2 H atoms (2 protons + 2 e-) from substrate (glucose) and delivers 2 e-s + 1 proton of H to NAD+ forming NADH, other H+ released to solution

E.T.S. (electron transport chain) - series of acceptor/donor molecules with increasing electronegativity embedded in inner membrane of mitochondria

Generation of ATP:

1. oxidative phosphorylation - production of ATP using energy derived from the redox

reactions of the E.T.S. (90% ATP generated in this manner)

2. substrate-level phosphorylation - formation of ATP by directly transferring a P to ADP from intermediate substrate in catabolism

3 steps involved in the breakdown of glucose:

1. glycolysis
2. Krebs' cycle
3. E.T.S.

Glycolysis " glucose breaking" - process by which glucose is broken down into pyruvate producing ATP

-occurs in cytosol of all living things

-note investment & production of ATP

-3 main processes:

1. activation
2. removal of H
3. formation of ATP

Krebs' cycle - named after Hans Kreb, continuing set of reactions

-occurs in mitochondria

-products of glycolysis (2 pyruvates) readied:

-2 $C_3H_4O_3$

1. 2 NAD+ remove 2H to form NADH + H^+

2. 2 CO_2 given off as waste to cytosol

3. molecule of coenzyme A (CoA) is needed leaving 2C compound Acetyl CoA (C_2H_2O)

-Acetyl CoA enters Krebs' cycle, attaches to 4C oxaloacetate, water added, 6C citrate results

-citrate loses H_2 to form NADH + H^+, CO_2 released

-5C ketoglutarate produced

-NAD^+ removes H_2 to form NADH + H^+, CO_2 released

-succinyl CoA attached, ADP + P forms ATP

-4C succinate produced

-FAD (flavin adenine dinucleotide) removes H_2 to form $FADH_2$ changing succinate to 4C fumarate

-water added changing fumarate to malate

- NAD^+ removes H_2 to form NADH + H^+

-4C oxaloacetate results

Overall results of Krebs' cycle:

-lost 6 molecules of CO_2 (waste)

-added 4 molecules of H_2O

-produced 2 ATP's

-produced 8 NADH

-produced 2 $FADH_2$

Electron Transport Chain - NADH and $FADH_2$ from Krebs' cycle pass excited e-s (from H_2) down chain of acceptor/donors to final acceptor, oxygen (1/2 O_2), water results

NADH NADH

NAD^+ H^+ e- e- e- e- H^+ NAD^+

O O

H H

H^+ H_2O H_2O H^+

Electron Transport Chain makes no ATP directly, but sets up H^+ gradient

NADH through E.T.S. (embedded in membrane) gives 2 e-s to chain H^+ released to intermembrane space, 2 e-s passed to 1/2 O_2 and 1/2 O_2, $2H^+$ from matrix ----------> produces water

High concentration of H^+ outside membrane, follows gradient, enters through ATP synthase ------------------> produces ATP

Chemiosmosis - coupling of exergonic electron flow down E.T.S. to endergonic ATP production

Proton-motive force - potential energy stored in the form of an electrochemical gradient, generated by the pumping of H^+ across biological membranes during chemiosmosis

Tally of ATP's produced during cellular respiration:

Glycolysis - 2 ATP , 2 NADH (must be shuttled, burns 2 ATPs)

Krebs' cycle - 2 ATP , 8 NADH , 2 $FADH_2$

+
----

4 ATP 10 NADH 2 $FADH_2$

E.T.S. - for each NADH gives 3 ATPs, for each $FADH_2$ gives 2 ATPs

----

4 ATP 30 ATP 4 ATP = 38 ATP

(shuttle) - 2

Total = 36 ATP

Aerobic respiration - with oxygen, more efficient

Anaerobic respiration - without oxygen, necessary to replinish NAD^+

All organisms go through glycolysis, depending on whether oxygen is present determines aerobic or anaerobic

Facultative anaerobes - organisms that produce ATP aerobically through respiration when oxygen is present, but can switch to fermentation in oxygen absence

2 types of anaerobic respiration:

1. alcoholic fermentation - conversion of products of glycolysis (pyruvate) into alcohol with CO_2 as by product
   - used by a few organisms including yeasts
   - what causes bread to rise (CO_2 given off)
   - what causes bubbles in beer
2. lactic acid fermentation - conversion of products of glycolysis (pyruvate) to lactic acid
   - used by some organisms, particularly anaerobic bacteria

-used in food industry to make yogurt and cheese

PHOTOSYNTHESIS

Photosynthesis - the process whereby sunlight is converted into chemical energy that is stored in glucose and other organic molecules

-supplies energy to all living organisms directly or indirectly

nutrition is obtained in 1 of 2 ways:

1. autotrophic - synthesizing organic molecules from inorganic raw materials (plants)

algae, some protists and some prokaryotes

-producers (autotrophs) - organisms that make their own food

2. heterotrophic - obtaining nutrients produced by other organisms (bacteria, fungi, animals)

-consumers (heterotrophs) - organisms that cannot make their own food

Site of photosynthesis is chloroplast, primarily within mesophyll of leaves

Mesophyll - tissue of the leaf's interior

Stomata - pores embedded in leaf epidermis that allows substances in and out

Photosynthesis equation:

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

C.B. van Neil (1930's) - hypothesized that plants split water as a source of H, releasing O_2 as a by-product

Photosynthesis occurs in 2 stages:

1. light reaction - convert solar energy to chemical energy, occurs in thylakoids, produces ATP through photophosphorylation and $NADPH_2$

2. Calvin cycle - incorporates CO_2 from air into organic molecules through carbon

fixation, uses products of light reaction (ATP & $NADPH_2$) to form sugar, occurs in stromata

Spectrophotometer - device that measures the amount of light of different wavelengths absorbed or reflected by a solution

-gives an absorption spectrum - shows the range of a substance's ability to absorb various wavelengths of light

Action spectrum - profiles the biochemical activity in response to certain colors or wavelengths

Sunlight - form of energy that travels in waves

-electromagnetic spectrum

Pigment - substance that absorbs or reflects light

-chlorophyll a - blue-green

-chlorophyll b - green-yellow

-carotenoids - yellow-orange (photoprotection)

Chlorophyll - principal pigment of green plants

Sunlight composed of different photons (energy packets). Photons are of different energies, each pigment has a certain photon capturing ability (i.e. each pigment can absorb certain wavelengths of light).

Chlorophyll absorbs wavelengths on each end of the visible spectrum, but reflects light within 500 - 600 nm range

-structure of chlorophyll

Photons of energy from sunlight are absorbed by specific chlorophyll a molecule

(P700), this energy excites the outer 2 e-s of magnesium atom (core of chlorophyll molecule). 2 e-s escape Mg hold and thus excited, leave chlorophyll molecule. Outside chlorophyll molecule the 2 e-s are picked up by an electron accept/donor. This acceptor/donor passes the 2 e-s to protein, ferredoxin (Fd). Ferredoxin must "decide" to either transfer 2 e-s to series of cytochromes (acceptor/donors) along E.T.C. (cyclic) or pass 2 e-s to $NADP_+$.Ferredoxin decides to pass 2 e-s to cytochromes of E.T.C. The stored energy of e-s is channeled out and used to combine a phosphate to ADP (cyclic phtophosphorylation) in the formation of ATP. The 2 e-s (still intact, just not "excited" any longer) are passed along chain until eventually returned to chlorophyll molecule.

In cyclic electron flow or photosystem I, light energy is absoprbed and converted into stored chemical energy as ATP.

Ferredoxin decides to pass 2 e-s to another acceptor/donor called $NADP_+$, $NADP_+$ becomesNADP2e- (it has 2 e-s too many, unstable, neg. charged).

P680, a specific chlorophyll a molecule, absorbs photons of energy from sunlight. This excites the 2 outer e-s of Mg atom core. The 2 e-s leave the Mg atom and the chlorophyll molecule. The e-s are received by an electron acceptor/donor. The a/d passes the e-s to carrier Pq, to 2 cytochromes, to protein Pc that makes up E.T.C. As e-s are passed, energy contained within is " spun off " to provide energy for combination of ADP and P (noncyclic photophosphorylation) in formation of ATP. The 2 e-s are then passed back along chain to photosystem I's P700 chlorophyll to restore its 2 lost electrons.

The NADP2e-s formed from P700 2e-s is negatively charged and in need of 2H to make $NADPH_2$. These 2H are supplied by the breakdown of H_2O.

H_2O within cell absorbs light which causes it to split (photolysis).

The 2H combine with NADP2e- to form $NADPH_2$.

O combines with other O to form O_2 which is released

2e-s are returned to P680.

-photosynthesis diagram

Light reactions - certain chlorophyll molecules absorb energy, pass this energy through e-s to finally be stored in chemical bonds with the production of ATP and $NADPH_2$

Calvin cycle (dark reaction) - 5C sugar RuBP (ribulose biphosphate) combines with one C from atmospheric CO_2. This reaction is catalyzed by rubisco (RuBP carboxylase). The newly formed 6C molecule splits into 2 - 3C molecules called PGA (3-phosphoglycerate)

Each PGA receives P from ATP and forms 3-bisphosphoglycerate, $NADH_2$ reduces 3-bisphosphoglycerate to G3P (glyceraldehyde 3-phosphate).

-structural models of PGA and G3P

The lost O atom combines with H_2 from $NADPH_2$ to form H_2O

The free NADP returns to light reaction to pick up more H^+

ATP becomes ADP + P and returns to light phase

REPRODUCTION IN CELLS

Genome - a cell's total hereditary endowment of DNA

Genes - the hereditary units (segments of DNA) that specify an organism's traits

Prokaryotes (bacteria) reproduce through binary fission:

-cell's genome replicates, each copy affixed to adjacent sites, cell doubles, pinches in, new cell wall laid down between, 2 daughter cells result

Eukaryotes - make new cells through mitosis

-somatic cells - all body cells except reproductive cells, diploid (2N)

-gametes - reproductive cells (egg and sperm), haploid (1N)

-chromosomes - tightly wrapped DNA around histones (special proteins) then coiled, carriers of genome

-chromatin - uncoiled DNA and proteins inside nucleus

-chromatid - one of the two identical parts that make up a pair of replicated chromosomes

-centromere - point of attachment between sister chromatids

Cell cycle - sequence of events that occurs in a cell from mitosis to mitosis

1. interphase - period of cell growth

G_1 - growth, cell doubles

S - DNA replicates

G_2 - synthesis of material for cell division

2. mitosis - division of the cell nucleus into 2 identical nuclei, each with same number of chromosomes as the parent cell, 5 steps:

Prophase - nucleoli disappear, chromosomes coil and become visible, centrosomes move toward poles, spindle begins to form

Prometaphase - nuclear membrane disappears, kinetochores located on centromeres of each sister chromatid, kinetochore microtubules connect kinetochores to opposite centrosomes

Metaphase - centrosomes at opposite poles, spincle aligns attached sister chromatids at metaphase plate

Anaphase - centromeres split seperating sister chromatids, newly formed chromosomes move to opposite poles by kinetochore microtubules elongate entire cell

Telophase - chromosomes at opposite poles have nuclear membranes formed around them, nucleoli reappear, chromosomes unwind into chromatin, cell pinches in

3. Cytokinesis - division of the cytoplasm of a parent cell and its contents into two daughter cells

-animals - microfilaments form ring inside cell membrane, deepens, pinches in two

-plants - vesicles align between new nuclei, vesicles fuse forming double membrane, forms cell plate, materials secreted into plate space and forms new cell wall

Cell division controls:

1. presence or absence of growth factors - receptors on cell membrane stimulated by attachment of growth factors

2. cell density - cells compete for nutrients and growth regulators so regulate themselves

-density-dependent inhibition - cells stop growing when they reach a certain density

3. anchorage - most cells require adhesion to a substratum

4. restriction point - checkpoint built into G_1 phase of cell cycle where cell decides to replicate or not

-G_0 phase - nondividing state, where most cells of human body stay

-muscles and nerve cells in G_0 phase

5. ratio of cytoplasmic volume to genome size

Rhythmic fluctuation in regulatory proteins pace the sequential events of the cell cycle

-protein kinases - enzymes that control the activities of other proteins (activate or deactivate a protein by catalyzing the phosphorylation of protein by P from ATP thereby changing conformation of protein

-cyclins - regulatory proteins whoose concentrations flutuate cyclically

-cyclin-dependent kinases (Cdks) - kinase that is active only when attached to cyclin

-MFP-cyclin - Cdk complex that controls cell's passage from interphase to mitosis

Cancer cells:

-ignore density-dependent inhibition

-can stop dividing at random points in cell cycle

tumor - mass of cancer cells within normal tissue

benign - cancer cells remain at original site (surgically removed)

malignant - concentration of cancer cells that impair the functions of one or more organs

metastasis - spread of cancer cells beyond their original site

MEIOSIS AND SEXUAL LIFE CYCLES

Heredity - the continuity of traits from one generation to the next

Variation - differences exhibited among offspring from same parents

Genetics - the scientific study of heredity and variation

Genes - hereditary units, sequence of nucleotides that specify the amino sequence of proteins, segments of DNA

-locus - gene's location on chromosome

Reproduction:

-asexual - only one parent, offspring genetically identical to parent, produces clones (group of genetically identical individuals)

-sexual - involves 2 parents, results in genetic variation

Life-cycle - the generation-to-generation sequence of stages in the reproductive history of an organism

Karyotype - picture of an individuals chromosomes

Homologous chromosomes (homologues) - chromosomes that make up a pair (1 set maternal, 1 set paternal)

-same length

-same centromere position

- same staining pattern

-carry genes for same trait at same loci

Autosomes - homologous pairs 1 - 22

Sex chromosomes - pair 23

- X X for female

- X Y for male

Fertilization (syngamy) - union of gametes (egg and sperm)

Zygote - fertilized egg with two haploid sets

Meiosis - process of cell division that reduces chromosome number by half, occurs in gonads (ovaries - female, testes - male)

Variations of sexual life cycles:

1. animals
2. some fungi and algae
3. plants and some algae (alteration of generation)

Sporophyte - multicellular diploid stage

-meiosis in sporophyte produces haploid spores

Gametophyte - multicellular haploid stage from mitotic division of spore

-produces gametes through mitosis

Meiosis and mitosis differences:

1. Prophase I

   -synapsis - homologous chromosomes pair up forming tetrads

   -chiasmata - sites of crossing over between homologous chromosomes

2. Metaphase I

   -homologous chromosomes align at metaphase plate

3. Anaphase I

   -homologs, each with attached sister chromatid, seperate and move to opposite poles

Sexual life cycles insure genetic variation through:

1. Independent assortment of chromosomes - random alignment of homologous pairs along metaphase plate, each orients independently of others

-number of combinations of chromosomes possible for gametes is 2^n where n = haploid number of organism (human is 23 so about 8 million)

2. crossing over

-during Prophase I formation of tetrads, homologs exchange chromosomal arms at chiasmata, results in chromosomes with combinations of maternal and paternal genes

3. random fertilization - union of one out of 8 million possible chromosome combinations of egg and sperm (8 million X 8 million = 64 trillion)

GENETICS

Character - a heritable feature (example - eye color)

Trait - variant for a character (example - blue, green, brown)

True-breeding - self-pollinated organism that produces offspring same as them (purebred)

Hybridization - crossing of two purebred individuals

Monohybrid cross - cross that involves a single pair of contrasting traits (tracks a single trait)

Dihybrid cross - cross that involves two pairs of contrasting traits

P generation - purebred parents

F_1 generation (first filial) - offspring of P

F_2 generation (second filial) - self-pollinated F_1's

Alleles - alternative forms of a gene

- -dominant - expressed allele
- -recessive - masked allele

Mendel's hypothesis:

1. different alleles account for variations in inherited traits
2. for each trait, an organism inherits 2 alleles, one from each parent
3. if alleles differ, one will be dominant, other recessive
4. alleles for a trait segregate during gamete production (each gamete receives only one allele)
    - -if true-breeding, all alleles the same
    - -if hybrid, 50% dominant, 50% recessive

Law of segregation - the members of each pair of alleles separate when gametes are formed

Law of independent assortment - pairs of alleles separate independently of one another during gamete formation

Homozygous - organism possessing two alike alleles (TT or tt)

Heterozygous - organism possessing unalike alleles

Phenotype - physical appearance

Genotype - genetic makeup

Punnett square - diagram used to predict the probable outcome of a cross

Test cross - crossing of an individual of unknown genotype with a homozygous recessive individual

Probability - likelihood that a specific event will occur

- Probability = $\frac{\text{no. of one kind of event}}{\text{no. of all events}}$

-scale ranges from 0 to 1

- independent events - outcome of one event unaffected by previous event

-rule of multiplication - chance that 2 or more independent events will occur together calculated by multiplying each independent event together (probable event X probable event = chance) (example - 1/2 X 1/2 = 1/4)

-rule of addition - probability of an event that can occur in 2 or more different ways is sum of separate probabilities (example - What is the probability within a mono-hybrid cross that the offspring within F_2 will be heterozygous ? 1/4 + 1/4 = 1/2)

Incomplete dominance - condition in which a trait is intermediate between two parents

(example - snapdragons, red X white = pink)

Codominance - two dominant alleles expressed at the same time

Multiple alleles - traits determined by 3 or more alleles (example - blood types)

Pleiotrophy - ability of a single gene to have multiple effects

Epistasis - a condition in which a gene at one locus alters the expression of a gene at a second locus; inherited independently

Quantitative character - a heritable feature in a population that varies contnously as a result of environmental influences and polygenic inheritance (example - skin color)

Polygenic inheritance - additive effect of two or more genes on a single phenotypic character (example - eye color, skin color)

Norm of reaction - range of phenotypic possibilities for a single genotype, as influenced by the environment

-broadest for polygenic characters

Multifactorial - traits influenced by genetic and environmental factors

Pedigree - family tree tracing a trait through several generations

Carrier - individual heterozygous for disorder

Genetic disorders:

-dominant alleles - generally die before child-bearing age, results in decrease of that allele in gene pool

-recessive - must have homozygous state for expression of disorder

MOLECULAR INHERITANCE

Scientist contributing to the discovery of DNA as the carrier of the genetic code:

-Frederick Griffith (1928) - British scientist discovers transformation

1. 2 strains of bacteria

disease-causing (smooth) S-strain

harmless (rough) R-strain

2. injected mice with each

3. mice injected with harmless survived

mice injected with disease-causing developed pneumonia and died

4. injected with heat killed disease-causing and survived

5. injected with live harmless and heat-killed mixture, mice developed pneumonia and died

transformation - a change in phenotype due to an assimilation of external genetic material by a cell

-Oswald Avery (1944) American bacteriologist along with Colin MacLeod and Maclyn McCarty performed Griffith's experiment using enzymes geared at destroying first lipids, then carbohydrates, next proteins, then RNA and DNA; each time transformation occurred except when DNA was destroyed. They concluded that DNA was the transforming factor.

Alfred Hershey & Martha Chase (1952) American scientists used bacteriophages to determine that DNA carried genetic information. Virus contains protein coat and nucleic acid (DNA or RNA) core. They used radioactive isotope sulfur-35 ($_{35}S$) to label protein and phosphorus-32 ($_{32}P$) to label DNA of T_2 virus that infects <u>E. coli</u>

bacteria. They waited, tested bacteria, found bacteria contained phosphorus.

phages - short for bacteriophages, viruses that infect bacteria

-Erwin Chargaff (1947) American biochemist discovered that in any sample of DNA, the number of A equaled the number of T, and C = G

-Rosalind Franklin - using British physicist Lawrence Bragg's x-ray techniques recorded the structure of DNA as a helical pattern

double helix - DNA's structure, 2 polynucleotide strands wound into a spiral shape

-James Watson, 25 year old American biochemist, and Francis Crick, British physicist, (1953), using compiled data of Rosalind Franklin developed a model for DNA. Awarded Nobel Prize along with Wilkins for discovering the structure of DNA

Mathew Meselson and Franklin Stahl (late 1950's) confirmed Watson's and Crick's theory of DNA replication whereby parental DNA seperated, each strand built, result was 2 DNA molecules each consisting of one original strand and one newly formed strand.

DNA (deoxyribonucleic acid) - double-stranded nucleic acid that stores and transmits genetic information from one generation to the next. Contains sugar deoxyribose, phosphate group, and nitrogenous bases A, T, C, and G, located in nucleus.

-purines - organic molecules with a double ring of carbon and nitrogen, adenine and guanine

-pyrimidines - organic molecules with a single ring of carbon and nitrogen, cytosine and thymine

Replication - the process of the duplication of a DNA molecule

-begins at origins of replication, specific sites with specific sequences of nucleotides where enzyme DNA helicase attaches causing breakage of H bonds, creates replication "bubbles"

-replication proceeds in both directions

-replication fork - ends of replication bubble forming where new strands of DNA are elonating

-DNA polymerase - enzyme that attaches new nucleotides to complementary strand during elongation

-nucleoside triphosphate converted to nucleotide by hydrolysis of phosphate

-antiparallel strands - sugar-phosphate backbone run in opposite directions

-DNA polymerase can add nucleotides only to free 3' end so elongation is in 5' to 3' direction

-leading strand - DNA strand in 5' to 3' direction

-lagging strand - DNA strand in segments 3' to 5' then joined by enzyme DNA ligase

-Okazaki fragments - segments of lagging strand

Priming DNA synthesis:

-DNA polymerase cannot initiate synthesis of a DNA strand

-primer - short stretch of RNA (about 10 nucleotides long) that initiates synthesis of new DNA strand

only one primer required for leading strand

each Okazaki fragment requires primer

-primase - enzyme that joins RNA nucleotides to make primer

-enzyme replaces RNA with DNA version

-ligase joins all fragments into a strand

Proofreading:

-mismatch repair - fixes mistakes when DNA is copied

DNA polymerase in bacteria

DNA polymerase plus about 50 other identified enzymes in eukaryotes

excision repair - segment of DNA cut out by enzyme, new nucleotides replace excised area

PROTEIN SYNTHESIS

Auxotroph - nutritional mutant that is unable to synthesize and cannot grow on a medium lacking certain essential molecules normally synthesized by wild-type strains of the same species. Such a wild type is a prototroph.

One gene-one enzyme hypothesis - hypothesis formulated by George Beadle and Edward Tatum which states that the function of a gene is to dictate the production of a specific enzyme

One gene-one polypeptide hypothesis - a single gene codes for single polypeptide change which can translate into a protein

RNA - nucleic acid composed of sugar ribose, phosphate group and nitrogenous bases A, U, C, and G; acts as messenger between DNA and ribosomes, travels outside the nucleus, single stand (ribose contains one more OH than deoxyribose)

Transcription - synthesis of RNA under the direction of DNA; process whereby a molecule of DNA is copied into a complementary strand of mRNA

-enzyme RNA polymerase attaches to DNA molecule causing unzipping; free floating bases pair up along DNA template strand producing mRNA strand from 5' to 3' end (nucleotides can only be added to 3' end), RNA polymerase synthesizes mRNA together, AUG acts as "start" signal, elongation of mRNA continues until "stop" codon reached, newly formed mRNA released, leaves nucleus, travels to cytoplasm

-codon - 3 nucleotide sequence of mRNA

-reading frame - sequence of nucleotides from start to stop

-transcription unit - entire stretch of DNA that is transcribed into a single RNA molecule, in eukaryotes represents a single gene, in prokaryotes may code for several related proteins

-3 key steps to transcription:

1. binding of RNA polymerase to promoters (initiation site and several nucleotides upstream)

transcription factors aid polymerases in search of promoters

TATA box - short segment of T's and A's about 25 nucleotides long that act as a flag for transcription factors for the binding of RNA polymerase II

2. elongation - RNA polymerase II unwinds double helix, one turn at a time, separates and exposes about 10 DNA bases, adds nucleotides to 3' end of mRNA molecule

3. Termination - "stop" signal is reached, RNA released

most common sequence in eukaryotes - AATAAA

Translation - the decoding of a mRNA message into a polypeptide chain (protein)

-mRNA binds to ribosome, tRNA with attached amino acid deposits its amino acid that links with peptide bond and creates the polypeptide chain

-anticodon - 3 nucleotide sequence of tRNA

-process of translation:

1. enzyme aminoacyl-tRNA synthetase matches correct amino acid to tRNA, site specific, attaches through hydrolysis of ATP

2. ribosomal subunits large and small combine to form functional ribosome

P site holds tRNA with polypeptide chain, A site holds tRNA with amino acid to be added, mRNA held within ribosome is held close to tRNA where ribosome catalyzes addition of amino acid to carboxyl end of polypeptide

-stages of translation:

1. Initiation - small ribosomal subunit attaches to mRNA, initiator tRNA with anticodon UAC base pairs with codon AUG (start) carrying amino acid methionine, large subunit joins, initiation factors aid in joining, energy through GTP spent

2. Elongation - amino acids added with aid of elongation factors

-codon recognition - mRNA codon in site A forms H bond with anticodon, hydrolysis of phosphate bond from GTP

-peptide bond formation - component of large ribosomal subunit catalyzes formation

of peptide bond between P site's polypeptide and A site's amino acid

-translocation - tRNA at site P dissociates from ribosome, A site's amino acid moves to P site, movement brings in next amino acid to A site, requires energy through hydrolysis of GTP

3.Termination - "stop" codon (UAA,UAG,UGA) reached, protein release factor binds to stop in the A site causing ribosome to add H_2O molecule to end of polypeptide which hydrolyzes completed polypeptide from tRNA in P site, frees polypeptide. Ribosomal subunits separate.

-polyribosomes - clusters of ribosomes attached to same mRNA, producing many proteins

-peptide bond

-translation from the language of nucleotides to the language of amino acids

Coding for amino acids is universal. Every organism has the same genetic code.

Differences among prokaryote and eukaryotes:

-prokaryotes (bacteria) - translation and transcription occur simultaneously

-eukaryotes - nuclear envelope results in compartmental translation

RNA processing - process of altering RNA before leaving nucleus in eukaryotes

-5' end capped with modified G (guanine) helps protect from hydrolytic enzymes, flag for small ribosomal subunits

-3' end - enzyme adds a poly-A tail, 30 to 200 A's (adenines), helps inhibit degradation

RNA splicing - noncoding segments called introns are excised by enzymes then exons, coded segments, are spliced together before RNA leaves nucleus

Mutations - changes in the genetic makeup of a cell:

Transition mutation - purine for purine

Transversion mutation - purine for pyrimidine

Point mutations - change that occurs in only one nucleotide

1. silent - single base pair change but codes for same amino acid
2. missense - single base pair change that results in new amino acid
3. nonsense mutation - codes for wrong amino acid, can stop translation, lead to nonfunctional proteins
4. frameshift -insertions and deletions of one or two base pairs that causes reading frame shift, yeilds mutant phenotypes

Mutagens - factors in the environment that can cause mutations in DNA (example - radiation)

Mutations ultimately provide the variation upon which natural selection acts.

VIRUSES AND BACTERIA

Viruses - consist of DNA or RNA (not both) and capsid (protein coat), some have viral envelopes (masking devises), parasites

Bacteriophage (phage) - viruses that invade bacteria

Host range - limited number of host cells that a virus can infect, due to recognition sites of protein on virus and receptor molecules on host cell surface

Lytic cycle - reproductive cycle of virulent viruses that includes:

attachment (att)

entry of viral nucleic acid

destruction of host DNA

use of host's cellular machinery to make viral parts

assembly of new viruses

lysing of host cell

Lysogenic cycle - viral reproductive cycle in which viral nucleic acid is incorporated into host's DNA (prophage), and is copied along with host DNA, under favorable conditions viral nucleic acid exists host DNA and begins lytic cycle

Temperate virus - virus capable of both lytic and lysogenic modes of replication

Retrovirus - virus with enzyme reverse transcriptase that transcribes DNA from RNA (example - HIV)

Vaccine - a weakened or killed virus that when injected into host stimulates the body's immune system

Oncogene - viral genes directly involved in triggering cancerous characteristics in cells

Carcinogen - nonviral, cancer-causing agents

Viroids - molecules of naked RNA that infect plants

Prions - infectious protein molecules that effect animal cells

Recombination - the combining of genetic material from two individuals into the genome of a single individual

Bacterial mechanisms of genetic recombination:

1. transformation - alteration of a bacterial cell's genotype by the uptake of naked, foreign DNA from surrounding environment

2. transduction - phages transfer bacterial genes from one host to another

-generalized - portion of host DNA inadvertently placed inside phage capsid, when injected into new host can replace homologous region of cell's 2nd chromosome (like crossing-over)

-specialized - incorporated phage DNA carries adjacent host's DNA with it

3. conjugation - direct transfer of genetic material between 2 bacterial cells

-F (fertility) plasmid - "male" bacteria (F_+) transfers plasmid by way of connecting with pili to "female" (F-) bacteria through cytoplasmic bridge

Episome - plasmids that can replicate either as an extrachromosomal molecule or as part of the main bacterial chromosome

R plasmids - antibiotic plasmids of bacteria, can be transferred through conjugation

Transposons - pieces of DNA that can move from one location to another in a cell's genome

-from one locus to another within a chromosome

-from plasmid to chromosome

-from plasmid to plasmid

-not site specific, inserted anywhere

-conservative transposition - gene(s) do not copy before move so number of copies of gene(s) preserved within genome

-replicative transposition - transposon replicates at original site and copy inserts at another location

-Insertion sequences - simplest transposons, consist of only the DNA sequence for the act of transposition and the gene for transposase (enzyme that catalyzes transposition)

-transposase recognizes inverted repeats, binds, holds close together, catalyzes DNA cutting and resealing

-insertion sequences cause mutations intrinsic to cell, may increase or decrease production of protein by insertion into regulatory regions of DNA that encode transcription rates

-Complex transposons - include 2 insertion sequences and genes in the middle, behave as single transposon

-R plasmids moved in this manner

Metabolic control in bacteria:

1. vary the numbers of specific enzyme molecules

-regulate the expression of a gene

tryptophan build up - cell stops making enzymes of trp pathway, occurs at transcription, the synthesis of mRNA

2. vary the activities of enzymes already present

more immediate

genes switched on and off by changes in metabolic status of the cell

-structural genes (genes coding for polypeptides) - grouped together on chromosome

consist of 5 genes for trp

single promoter serves all 5

mRNA contains start and stop codons for all 5

Operator - switch, segment of DNA, positioned in promoter or between promoter and structural genes, controls the acess of RNA polymerase to structural genes

Operon - stretch of DNA required for enzyme production (structural genes, operator and promoter combined)

-normally in "on" position

-switched "off" by repressor (protein that binds to operator thereby blocking attachment of RNA polymerase to promoter)

-repressors are site specific

Regulatory gene - gene that codes for repressor, located before operon it controls. Transcription of regulatory gene produces mRNA that translates into repressor protein, reaches operator through diffusion

Operator may be on or off dependent upon number of active repressor molecules present

-initially trp repressor inactive, becomes active when binds to molecule of tryptophan

Corepressor - small molecule that cooperates with repressor protein to switch an operon off

-more trp, more active repressor, more switched off

Repressible enzymes - enzymes whose synthesis is inhibited by a metabolic end-product (example - trp)

-usually function in anabolic pathways, doesn't make what's already present

Inducible enzymes - enzymes whose synthesis is induced by a chemical signal

-usually function in catabolic pathways, doesn't produce enzyme with no job to do

Lac operon (lactose metabolism):

1. regulatory gene preceeding operon codes for repressor protein that binds to operator switching off operon, innately active

2. inducer - specific molecule that inactivates repressor (for lac operon - allolactose)

-in presence of lactose, allolactose binds to lac repressor altering conformation so can't attach to operator (lac operon can produce mRNA for enzymes of lactose pathway).

-for breakdown of lactose must also have absence of glucose (glucose preferred by E. coli for glycolysis)

CAP (catabolite activator protein) - accelerates transcription of operon by adhering to promoter and facilitating binding of RNA polymerase

-catabolites - molecules that can be consumed by catabolic pathways (example - lactose)

cAMP (cyclic AMP) - derivative of ATP, accumulates in absence of glucose

-forms complex with CAP that attaches to lac promoter and stimulates transcription of genes for lactose catabolism

RECOMBINANT DNA TECHNOLOGY

Genetic engineering - the manipulation of genetic material for practical purposes

Biotechnology - the manipulation of living organisms or their components to perform practical tasks or provide useful products

Recombinant DNA - combination of DNA from 2 sources

Cloning of recombinant DNA - process of making many exact copies of DNA or genes, can be used for:

1. mass production of protein product (example - insulin, human growth hormone, tissue plasminogen activator)
2. incorporate an organism with a metabolic capability not previously possessed (example - pest resistance in crops, bacteria to degrade oil spills)
3. create multiple copies of gene itself for study

Genetic engineering requires:

1. restriction enzymes - cut DNA (restriction) at precise locations, recognize specific nucleotide segments (restriction sites)

   -restriction-enzyme recognition sequence is a palindrome (same sequence of 4 to 8 nucleotides found on both strands but run in opposite direction)

   -restriction fragments - double-stranded DNA fragments with single-stranded ends

   -sticky ends - single-stranded exposed section of DNA at site of restriction

   can form hydrogen-bonded base pairs with complimentary single-stranded stretches of other DNA cut with same restriction enzyme

   temporarily bonded by hydrogen bonds

   can be permanently bonded with DNA ligase

2. vectors - transfer agent, usually bacterial plasmids, viruses, or yeast plasmids

3. host organism - cells compatible with recombinant DNA, bacterial most common due to ease of insertion and rapid growth

-differences between prokaryote and eukaryote transcription and translation techniques cause problems

-yeast (eukaryote) best vector for eukaryotes

Steps using bacterial plasmid to clone genes:

1. isolation of bacterial plasmid and human DNA gene
2. digestion of both with same restriction enzyme
3. sticky ends of each pair
4. enzyme DNA ligase join DNA molecules
5. recombinant plasmid with human gene transformed into bacterial cell
6. reproduction of bacterial cell
7. identification of desired strain

Genomic library - set of clones each carrying different genes, can either be plasmid or phage libraries

-problem with using prokaryotic bacteria to clone eukaryotic genes is overcome by using mRNA instead of eukaryotic DNA

cDNA - complementary DNA formed from mRNA that contains only exons

-contain no promoters so must be joined to a bacterial promoter to be functional

- mRNA removed from cell, DNA strand made from mRNA, 2nd strand made from 1st strand using DNA polymerase

Gel electrophoresis - process that separates macromolecules (nucleic acids or proteins) on the basis of size, electrical charge, and other physical properties

Electroporation - process of getting DNA into eukaryotic cells by using brief electrical pulse which causes holes in plasma membrane for DNA entry

Hybridization - base pairing between gene and a complementary sequence on another nucleic acid molecule

Probe - complementary molecule of RNA or DNA used to attach to specific gene through hydrogen bonding of base pairs in detection of gene

PCR (polymerase chain reaction) - technique of amplifying DNA segments in vitro using primers (specific to desired segment), DNA polymerase and nucleotides A,T,C, and G

Southern blotting - hybridization method using probes to attach to mRNA to determine whether a gene is made into mRNA

RFLPs (restriction fragment length polymorphisms), pronounced "riflips" - differences in DNA sequence on homologous chromosomes of restriction fragment lengths; used as genetic markers

KINGDOM MONERA

Monerans - unicellular, prokaryotic organisms, most obtain nutrition through absorption, some are photosynthetic or chemosynthetic, have ribosomes different from other other organisms, reproduce asexually through binary fission, sexually through conjugation

Carl Woese studying rRNA sequences in organisms has suggested a three domain system of classification. Prokaryotes are divided into the Archaea and Bacteria. Eukaryotic organisms are placed in the Eucarya domain. These domains would be placed above the kingdoms in the classification scheme.

Bacteria - single-celled prokaryotes of the kingdom Monera

-most contain single, double-stranded, circular chromosome

-some contain plasmids, small circyular DNA

-produce endospores, dehydrated cells with thick walls that can withstand harsh conditions

Reproduction:

asexually through binary fission - divides in half producing two identical daughter cells

sexually through conjugation - process whereby different cells align, transfer genetic information by way of pilus and conjugation bridge

Archaebacteria - group of monerans that live in harsh environments

-methanogens - live in O_2 free environment and produce methane gas

- thermophiles - live in extremely hot water (60 - 250 C)

- halophiles - live in extremely salty environment

Eubacteria - true bacteria

-diagram typical bacteria

Bacteria are classified according to:

1. shape -

bacilli (sing. bacillus) - rod shaped

cocci (sing. coccus) - spherical

spirilla (sing. spirillum) - spiral

strepto - chain

staphyl - cluster

2. cell wall composition - through Gram stain

Gram-positive - retain purple dye, single cell wall of carbohydrate and protein, large amounts of peptidoglycan, more susceptible to antibiotics

Gram-negative - red colored, two layered cell wall, inner carbohydrate and protein, outer lipopolysaccharides, less peptidoglycan, outer membrane, harder to treat with antibiotics

peptidoglycan - polymers of modified sugars cross-linked by short polypeptides

capsule - additional outer protective covering of some bacteria, also provides adhesion

3. nutrition - refers to how an organism obtains energy and source of carbon for synthesizing organic compounds

photoautotrophs - use sunlight and CO_2

chemoautotrophs - use inorganic molecules and CO_2

photoheterotrophs - use sunlight and organic molecules chemoheterotrophs - need organic molecules for energy and carbon source (most prokaryotes)

-saprophytes - absorb nutrients from dead and decaying matter

-parasites - absorb nutrients from hosts

Respiration:

-obligate aerobes - require O_2

-facultative anaerobes - use O_2 if present, but able to grow without it

-obligate anaerobes - cannot survive in O_2

Growth rate:

-most reproduce in 1 - 3 hours, some as fast as 20 minutes

-held in check by exhausting nutrients or accumulation of waste

-antibiotics - chemicals that inhibit growth of other organisms

Genetic recombination in bacteria:

-transformation - genes taken up from surrounding environment

-conjugation - genes transferred directly from one to another

-transduction - genes transferred between prokaryotes by viruses

mutation is the major source of genetic variation

Evolution of prokaryotes:

1.Glycolysis - breaks down organic molecules to produce ATP, no O_2 required

2.E.T.C. - chemiosmosis using e- transfers along a chain of membrane proteins to pump H+ ions, gradient difference powers ATP generation

3. Photosynthesis - light absorbing pigments on membrane surfaces, coupled with

E.T.C. to produce ATP (example - bacteriorhodopsin)

- used pigments to drive e-s from H_2S to NADP+, could be used to fix CO_2

4. Cyanobacteria - developed method of making compounds from H_2O and giving off O_2 from photosynthesis

5. Aerobic respiration began with O_2 availability

Signature sequences - taxon-specific base sequences at comparable locations in rRNA or nucleic acids

Symbiosis - ecological relationships between organisms of different species

-symbionts - those organisms involved in symbiosis

1. mutualism - both benefit

2. commensalism - one benefits, other unharmed

3. parasitism - one benefits (parasite) at expense of other (host)

Approximately 1/2 of all diseases in humans caused by bacteria

-most bacteria are harmless

-opportunistic - normally harmless, but become pathogenic when body defenses low

-pathogenic - cause disease

can cause disease by parasitizing human tissue (example - TB and leprosy)

can produce toxins:

1. exotoxins- proteins secreted by the bacterial cell, most potent poisons known (example - botulism)

2. endotoxins - components of Gram negative membrane, cause same symptoms, rash and fever

Koch's postulates - guidelines for microbiology

1. find same pathogen in each diseased individual investigated

2. isolate the pathogen from a diseases subject and grow the microbe in pure culture

3. induce the disease in experimental animals by reansferring the pathogen from the culture

4. isolate the same pathogen from the experimental animals after the disease develops

Monerans role in the biosphere:

beneficial:

-decomposers - help break down dead and decaying matter for recycling

-nitrogen fixation - take nitrogen in air and convert it into usable form

-symbiotic partners (example - E. coli in our intestines help digestion and produce vitamins)

-food production (cheese, yogurt)

-genetic engineering (insulin production), act as vectors

-bioremediation - restore environment

Harmful:

-cause diseases such as diptheria, TB, typhoid fever, tetanus, syphilis, cholera, bubonic plague

PROTISTA

Eukaryotes - membrane-enclosed nucleus, mitochondria, chloroplasts, endomembrane system, 9 + 2 flagella, multiple chromosomes consisting of linear DNA molecules compactly arranged with proteins, diploid stages in life cycles, mitosis, sex

Evolutionary trends -

1. specialized cells for different functions
2. colonization where each species benefited from the metabolic specialities of other species
3. compartmentalization of different functions within single cells

Endosymbiotic theory - eukaryotes evolved from symbiotic prokaryotes

-chloroplasts from photosynthetic prokaryotes (probably cyanobacteria)

-mitochondria from aerobic heterotrophic bacteria

Evidence to support:

-similarities between eubacteria and chloroplasts and mitochondria

-inner membranes of chloroplasts and mitochondria contain enzymes and transport systems similar to modern prokaryotes

-mitochondria and chloroplasts split like binary fission in bacteria

-DNA in circular units like plasmids of bacteria

-ribosomes of mitochondria and chloroplasts similar in size, biochemical characteristics and sensitivity to antibiotics akin to prokaryotic ribosomes

-base sequences of rRNA within chloroplasts and mitochondria more similar to rRNA of photosynthetic eubacteria than rRNA of eukaryotic cytoplasm

Archezoans (diplomonads) - organisms that lack mitochondria and plastids, contain two discrete haploid nuclei

-rRNA sequence identifies archezoans as the eukaryotes most closely related to prokaryotes (example - Giardia)

Acritarchs - oldest known protists fossils

-1992, paleobiologists discovered oldest acritarchs of 2.1 billion year old in Michigan rock

Protists - most unicellular, found in aquatic or damp environments, most are aerobic using

mitochondria for cellular respiration, all capable of asexual reproduction, some sexual, some produce cysts, can be photoautotrophic, heterotrophic or mixotrophic (photosynthesis and heterotrophic)

Protists divided into 3 groups based upon their nutritional means:

1. algae (plantlike)
2. protozoa (animalike)
3. absorptive (funguslike)

Protozoans- eukaryotic heterotrophs classified by means of locomotion

Rhizopoda - unicellular, move by means of cytoplasmic extentions called pseudopodia,

inhabit both fresh and marine environments, most free-living, some parasitic (amoebas)

Actinopoda - possess axopodia, slender pseudopodia that function in feeding and help organism to float, components of plankton, inhabit fresh water (heliozoans) and marine (radiozoans) environments

Foraminifera - exclusively marine, shells porous and hardened with calcium carbonate,

fossils used as markers for correlating sedimentary rock throughout the world

Apicomplexa - animal parasites producing infectious cells called sporozoites, complex

life cycle involving different host species (Plasmodium - causes malaria)

Zoomastigophora - free-living and symbiotic, some pathogenic, flagellated

(Trypanosoma - causes African sleeping sickness)

Ciliophora - use cilia to move and feed, contain both micro and macronuclei, repro-

duce asexually through binary fission, or sexually through conjugation (Paramecium)

Absorptive - ecological role as decomposers

Myxomycota (plasmodial slime molds) - heterotrophic, coenocytic feeding stage called

plasmodium

-life cycle

Acrasiomycota (cellular slime molds) - feeding stage of solitary cells that under stress

form an aggregate but remain seperated by their membranes

-life cycle

Oomycota (water molds) - cell walls of cellulose, consist of coenocytic hyphae, mostly

fresh water decomposers (potato blight)

Algae - eukaryotic , most photosynthetic, contribute half the organic material from

photosynthesis on the earth, classified by type of pigment contained, chemistry of cell wall,

and form of food stored

Dinoflagellata - most unicellular, some colonial, component of phytoplakton, both photosynthetic and heterotrophic (red tide)

Bacillariophyta - yellow or brown, silica walls, store oils (diatoms)

Chrysophyta - most colonial, yellow or brown, form cysts

Phaeophyta - largest and most complex algae, most marine, brown

-seaweed structure:

thallus - seaweed body that is plantlike but lacks true roots, stems, and leaves

holdfast - anchors the algae

stipe - stemlike structures, supports blades

blades - leaflike structure

-human uses of seaweed include food and agar

Rhodophyta - red, fresh but most marine, no flagellated stage

Chlorophyta - most fresh water, photosynthetic symbionts

Alternation of generation - the alternation of multicellular haploid and diploid forms in the life cycle of an organism

-sporophyte - diploid individual that produces reproductive cells called spores

- gametophyte - haploid individual that produces gametes

-heteromorphic - sporophyte and gametophyte forms differ in morphology

-isomorphic - sporophytes and gametophytes morphologically the same

-isogamy - union of gametes from opposite but isomorphic mating strains

-anisogamy - male and female gametes differ in size or morphology

-oogamy - type of anisogamy that has a flagellated sperm fertilizing a nonmotile egg

FUNGI

Fungi - eukaryotic heterotrophs mostly multicellular and multinucleated, cell walls of chitin, body composed of hyphae, sessile, reproduce sexually and asexually, obtain nutrition through absorption

Fungi are:

1. saprophytes - break down other organisms
2. parasites - live off and harm host
3. symbionts - live with other organisms whereby one benefits

Structure of typical fungus:

-hyphae (sing. hypha) - individual filaments

-mycelium - tangled mass of tiny filaments, forms body of fungus

-can be:

septate - contain cross walls

nonseptate - no cross walls

coenocytic - continuous cytoplasm with many nuclei

-chitinous walls - tough, flexible nitrogen-containing polysaccharide

Nutrition :

-enzymes produced in hyphae break down large organic molecules that are then absorbed through cell envelope

-nutrients used for growth primarily, some fungi can produce as much as 35 to 40 meters of hyphae in 1 hour

-growth occurs at tip of hyphae

haustoria - nutrient-absorbing hyphal tips that penetrate the tissues of host, characteristic of some parasitic forms

Kingdom fungi divided into 4 phyla (divisions) based upon method of sexual reproduction

and basic structure

-asexual reproduction:

1. budding - parent cell divides, produces bud that seperates from parent

2. regeneration - piece of mycelium breaks off and grows on own

3. spore production -

spore - reproductive cell that can remain dormant for long periods of time and can withstand harsh conditions

fruiting body - spore producing structure

-sexual reproduction involves the union of + and - hyphae that forms fruiting bodies

-syngamy - sexual union of cells from 2 individuals, occurs in two stages separated in time

1. plasmogamy - fusion of cytoplasm, 2 nuclei pair up but don't fuse

-dikaryon - fungal cell or mycelium containing 2 nuclei, can coexist and divide in tandem for years; nuclei fuse to form diploid cell that immediately goes through meiosis

2. karyogamy - fusion of nuclei

4 divisions of fungi based upon structures involved in plasmogamy, length of time spent as dikaryon, and location of karyogamy

1. Zygomycota, "common molds"

-terrestrial, hyphae lack septa (except to isolate reproductive structures)

-asexual - sporangia produce spores

-sexual - 2 hyphae (+ and -) fuse to form zygosporangium that produces 2N zygospore that undergoes meiosis and forms sporangium that releases N spores which can each form new N mycelium

-diagram of sexual and asexual reproduction

-rhizoids - anchor fungus, release digestive enzymes and absorb digested organic material

- stolons - stemlike hyphae that run along surface, connect rhizoids and transport nutrients

-sporangia - produce spores

-zygospore - diploid (2N) structure from fusion of + and - hyphae

-example of zygomycetes - Rhizopus stolonifer (typical bread mold), shower curtain mildew

2. Ascomycota, "sac fungi" - largest division

-conidia - spores

-ascongonium - female

-antheridium - male

-ascocarp - fruiting body, tips contain dikaryotic hyphae that are partitioned into asci, karyogamy occurs within asci, diploid nucleus divides by meiosis yielding 4 haploid nuclei, each divides once by mitosis, wall develops around each 8 nuclei to form ascospores

-diagram of sexual and sexual reproduction

-example - yeast (granules are actually ascospores), morel

3. Basidiomycota, "club fungi" - most mushrooms, tendency to reproduce sexually, best at decomposing wood component lignin, complex polymer

-basidium - spore producing structure

-basidiospore - spore that germinates to produce haploid primary mycelia

life cycle:

1. basidiospore germinates to produce 1N primary mycelia (two types - + and -)

2. secondary mycelia containing 2 nuclei (fusion of + and -)

3. upon favorable conditions, fruiting body (mushroom) begins

-diagram of sexual reproduction

-examples include mushrooms, shelf fungi, puffballs, and rusts

4. Deuteromycota, "imperfect fungi" - only reproduce asexually by production of conidia on specialized hyphae called conidiospores

-example - Penicillium, frequently grows on fruit, source of antibiotic penicillin; fungi that cause ringworm, athlete's foot, black spot on roses, and tomato blight

Lichens - symbiotic association of photosynthetic microorganisms (usually green algae or cyanobacteria) and fungi (usually ascomycete, some basidiomycete)

-algae provides fungus with food, secretes acids that aid uptake of minerals

-cyanobacteria fix nitrogen

-fungal hyphae retains water and minerals, allows for gas exchange and protects algae

-reproduction in lichens:

each symbiont reproduces independently

asexually by fragmentation

- soredia - specialized structures consisting of clusters of hyphae with embedded algae

Mycorrhizae - mutualistic associations of plant roots and fungi, greatly increases absorptive surface of plant roots, 95% of all vascular plants have mycorrhizae

Ecological impact of fungi:

1. principal decomposers, recycle nutrients
2. food spoilage
3. pathogenic - athlete's foot, vaginal infections, lung infections
4. food source
5. medicinal

Fungi evolutionary link with protists:

Chytrids - flagellated organisms with cell walls of chitin, absorptive nutrition, that form hyphae. Also contain enzymes and use metabolic pathways similar to fungus. Have similar protein sequence and nucleic acids.

PLANTS

Plants - eukaryotic, multicellular, photosynthetic, sessile, cell walls of cellolose, true tissue and organs, reproduce asexually by vegetative propagation or sexually by alteration of generation, mostly terrestrial.

-plant phylogenetic tree

Three main "organs" in plants:

1. roots - absorb water and dissolved nutrients from moist soil, anchor plants, hold plants upright, some store food (carrots, beets)

-2 types of roots:

taproot - primary plant root, grows deep into soil

fibrous roots - short, branched, threadlike roots close to surface

-structure of roots:

epidermis - thin, outermost layer of cells that take in water and nutrients; grow slender projections called root hairs that absorb nutrients by active transport; water moved into root hairs by osmosis

cortex - active transport of ions draws H_2O inward to center of root, may also store sugars or starches

endodermis - single layer thick at inner boundary of cortex, surrounds and encloses the vascular cylinder and stretches entire length of root. Each individual endodermal cell is surrounded on 4 sides by a waterproof strip called the Casparian strip. This prevents water and nutrients from flowing backwards. Active transport pumps nutrients to vascular cyclinder, water follows by osmosis, results in one way passage into vascular cylinder in plant roots.

vascular tissue of two kinds:

1. xylem - carry water and nutrients from roots to stems and leaves, thick cell walls that provide strength; dead cells (movement up only)

2. phloem - carry products of photosynthesis from one part of plant to another; alive and filled with cytoplasm (movement up and down)

root pressure - due to one way system, pressure (root pressure) builds which forces water into the xylem. Increased pressure in xylem pushes water through root into stem.

2. stems - hold plant's leaves to sun, conduct various substances between roots and leaves

4 types of tissue in stems:

1. parenchyma (pith) - tissue composed of thin-walled cells

2. vascular tissue (xylem and phloem) - conduct water, nutrients and plant products up and down the plant . Xylem makes up rings of trees.

3. vascular cambium - makes more xylem and phloem cells allowing stems to grow thicker

4. cork cambium - produces cork tissue (outer bark of trees)

-modified stems:

-rhizomes - thick, fleshy, creeping stems that grow either along or just beneath surface which contain buds from which leaves and stems grow (irises, canna)

-tubers - modified ungerground stems where food is stored (potatoes)

-bulbs - underground stems with food stored in layers of short, thick leaves

(tulips, daffodils)

-corms - underground stem with food stored in stem with thin leaves protecting it (crocuses, gladioli)

3. leaves - covered with waxy cutucle to prevent drying, capture sun's energy

-structure:

blade - flat, broad section

petiole - short stalk that connects blade to stem

veins - carry water, minerals and sugars throughout blade

-classified as either:

simple - consist of one blade (pine)

compound - consist of two or more blades, can either be:

pinnate - feather-like, leaves branch off midrib (ash, rose bush)

palmate - leaves radiate from central point (strawberry)

-internal structure diagram

epidermis - tough cube-shaped cells that form outer protective covering and do not contain chlorophyll

cuticle - waterproof layer that coats epidermis, slows evaporation

stomata - small openings formed by two specialized epidermal cells called guard cells that allow gas exchange in leaves (work by pressure)

Transpiration - evaporation of water from stomata

mesophyll - composed of parenchyma cells with chloroplast, where most photo-synthesis occurs

Transpiration-cohesion theory - explains how H_2O moves up plant against gravity. As water is lost through stomata creates low pressure, H_2O in xylem, H_2O moves from high to low, H_2O moves from xylem in stem, creates lower pressure in stem, H_2O from root moves into xylem stem in low area.

-cohesion - sticking together (polarity) of H_2O molecules aids this movement, H_2O molecules pulled along with other H_2O molecules

Sugars move from site of production or storage to needed sites by way of active transport regulated by water pressure.

Plants are divided in various ways:

1. vascular and nonvascular

vascular - contain vascular tissue - trees, vines and flowering plants

nonvascular - contain no vascular tissue - mosses, liverworts, hornworts

2. seedless and seed producing

seedless - do not form seeds

seed producing - form seeds, 2 types:

1. Gymnosperms - vascular plant that produces seeds enclosed in cones (pine, fir spruce, cypress, redwood)

2. Angiosperm - vascular plant that produces seed enclosed in fruit (apple, grape, tomato, cucumber, walnut)

3. life span:

-annual - plant that lives, reproduces and dies in 1 year (vegetables, garden flowers)

-biennial - plant that completes life cycle in 2 years (pansies, carrots, beets)

-perennial - plant that lives, reproduces and continues to grow year after year (trees)

4. seed structure:

-monocots - seed with one cotyledon, floral parts in multiples of 3, leaves have parallel veins, most with fibrous roots (grasses, corn, rice, wheat)

-dicots - seeds with two cotyledons, floral parts in multiples of 4 or 5, leaves with branching, netlike veins, most have taproot (fruit trees, roses, tulips, dandelions)

-chart comparing monocots and dicots

cotyledons - seed leaves of embryo, contain food source used by embryo after germination

Growth:

meristems - growing tissues of plants located at tips of roots, stem, branches, and in buds (where lwaves attach to stems)

-produce new cells by mitosis that specialize into vascular, dermal, or parenchyma

apical meristems - meristems at tips of roots and stems that cause plants to grow taller and roots deeper in soil

axillary meristems - meristems in buds that cause side branches on stems

-2 patterns of growth:

1. Primary growth - the elongation of stems and roots, occurs in all plants and involves

3 steps:

1. cell division - in apical meristem forms new cells

2. elongation - cells grow longer, pushes root through soil

3. differentiation - cells specialize into vascular, dermal, or parenchyma cells

2. Secondary growth - roots, stems, and branches of most gymnosperms grow wider

(woody vines, shrubs, trees)

-result of growth in lateral meristems (cambium) that are within and parallel to sides of roots and stems

Reproduction in flowering plants:

-diagram of flower

-flower - the reproductive structure of a flowering plant or angiosperm; modified stems

-stamen - male part of flower, includes filament and anther which produce pollen grains (sperm cells)

-pistil - female part of flower consisting of :

stigma - sticky structure where pollen lands

style - connects stigma to ovary

ovary - develops into fruit

ovule - structure in which egg develops, eventually becomes seeds

-sterile parts:

petals - colorful, attract pollinators

sepals - protective leaves at base, protect developing flower parts as they grow

Pollination - transfer of pollen from anther to stigma

-pollen lands on stigma, pollen tube grows through style to ovary carrying sperm along with it

Fertilization - union of egg and sperm

-double fertilization - occurs only in angiosperms, sperm fertilizes one egg that becomes the zygote, another sperm fertilizes two polar nuclei that forms endosperm tissue (3N)

- -zygote develops into embryo
- -ovule becomes seed
- -endosperm tissue forms fruit

Alteration of generation - the switching from diploid (2N) spore-producing generations to haploid (N) gamete-producing generations

-diagram of alteration of generation

PHYLOGENY OF ANIMALS

Animal - multicellular, eukaryotic, heterotrophic organisms that store food as glycogen, lack cell walls, most repoduce sexually

Patterns of development in animals:

-development - series of changes that produce a multicellular organism from a single-celled zygote

1.fertilization - sperm unites with egg to form zygote

2. zygote divides by mitosis (1 - 2 - 4 - 8 - 16 ....)

-Cleavage patterns:

cleavage - the progressive division of cells during embryonic growth, 2 forms:

1. Spiral cleavage (determinate cleavage) - cleavage planes are diagonal to polar axis and unequal cells are produced by the alternate clockwise cleavage around the axis of polarity (protostomes)

2. Radial cleavage (indeterminate cleavage) - cleavage planes are synnetrical to the polar axis, tiered effect (deuterostomes)

3. Blastula - hollow sphere of cells from sucessive divisions; each time getting smaller and smaller cells (overall size stays the same)

-blastopore - point at which cells fold inward

4. Gastrulation - process by which cells fold inward begins

-result of gastrulation - blastula divides into distinct layers, inside layer develops into the endoderm, outer layer into ectoderm, third layer (mesoderm) forms from pouches pinched off of ectoderm or endoderm

-function of layers:

Ectoderm - outer body covering (skin, hair, nails), nerve tissue, sense organs, brain.

spinal cord

Mesoderm - muscle, bone, connective tissue, peritoneum (lines body cavity of coelo-

mates), circulatory system, most excretory and reproductive system

Endoderm - digestive tract, lungs, many glands

Blastopore's fate determines protostome or deuterostome:

-blastopore becomes the mouth - protostome

-blastopore becomes the anus - deuterostome

Coelom - a body cavity formed between laters of mesoderm and in which the digestive tract and other internal organs are suspended

Advantages:

- body's organs located in a fluid-filled enclosure in which they can function without pressures from surrounding muscles

-fluid within cavity may act as circulatory system, without every cell of animal would have to be within short distance of O_2, H_2O, and other needed substances

-space for expansion of internal organs (accumulation of large numbers of egg and sperm)

-more efficient digestion and waste removal

Acoelomates - organisms without a coelom (flatworm)

Pseudocoelomates - organisms with a body cavity that is not a part of blood or digestive system, cavity develops between mesoderm and endoderm; lack epithelial lining derived from mesoderm found in true coelomates (roundworms)

Coelomates - organisms with true coelom arising from opening in mesodermal tissue during development with digestive, reproductive, and other internal organs suspended (mollusks, annelids, arthropods, ecinoderms, tunicates, vertebrates)

Symmetry - describes how an animal's body parts are arranged

1. asymmetrical - no definite form (amoeba)
2. spherical - organism shaped like a ball, floater (<u>Volvox</u>)
3. radial - parts radiate out from a central disk (starfish)
4. bilateral - left side is mirror image of right (many invertebrates and all vertebrates)

Support:

1. Hydrostatic skeleton - "skeletal" system in which support and movement are controlled by a water-filled body cavity
2. Exoskeleton - system of supporting structures covering outside of body
3. Endoskelton - system in which a rigid framework is located inside the body

Feeding:

1.Intracellular - digestion occurs inside the cell
2. Extracellular - digestion occurs outside the cell

Internal transport:

1. Diffusion - limiting; direct body surface to environment exchange
2. Open circulatory system - internal organs bathed in fluid
3. Closed circulatory system - blood contained in vessels which connect to organs

Respiration - exchange of O_2 and CO_2

-through skin then evolved organs for breathing - gills, mantle cavities, book lungs, tracheal tubes, air sacs, lungs

Excretion - rid body of excess water and wastes:

-evolutionary trends:

diffusion through body surfaces

specialized cells

tubules - absorb fluid from blood

nephridia - take in body fluids, filter, return water to body

kidneys

Response:

nerve nets - net of nerve cells

nerve cords or rings - concentrated nerve cells

cephalization - concentration of nerve cells in anterior of body

ganglia - clumps of nerve tissue

brain

Reproduction:

Asexual - single organism produces new organism identical to self

Sexual - two cells, normally from different individuals, unite to produce the first cell of a new organism

-Fertilization:

External - eggs fertilized outside the body

Internal - egg fertilized inside the body

Body layout:

dorsal

posterior anterior

ventral

Phylum Porifera (sponges) - no tissues, hermaphoditic, cross-fertilization, regenerate, budding, one-way water vascular system, spogin and spicules for support

Phylum Cnidaria (hydra, jelly-fish, sea anenome, corals) - two body plans (hydra and medusa), cnidocytes, nematocysts, one opening for mouth and anus

Class Hydrozoa - polyp emphasis

Class Scyphozoa - medusa emphasis

Class Anthozoa - polyp only

Phylum Ctenophora (comb jellies) - eight rows of comblike plates composed of cilia used for locomotion

Phylum Platyhelminthes - flame cells (excretory), regenerate, one opening

Class Tubellaria - flatworms

Class Trematoda and Monogenea - flukes

Class Cestoda - tapeworms

Phylum Nemertea - complete digestive tract, first with vascular system

-ribbon worms and proboscis worms

Phylum Rotifera (rotifers) - specialized organ systems, pathenogenesis

Phylum Nematoda - intenal fertilization, longitudinal muscles, decomposition

-pinworms and hookworms

Phylum Mollusca - foot, visceral mass, mantle, mantle cavity, radula, trochophore larva

Class Bivalva - clams

Class Gastropoda - snails

Class Cephalopoda - (closed circulatory system) - squid, octopus

Class Polyplacophora - chitons

Phylum Annelida - segmented, hermaphroditic, metanephridia (excretory)

Class Oligochaeta - earthworms

Class Polychaeta - polychaetes

Class Hirundinea - leeches

Phylum Arthropoda - exoskeleton, open circulatory system, molting, jointed appendages, classification based upon number of body segments and appendages, types of mouthparts, mrthods of development

Subphylum Trilobitomorpha - extinct trilobites

Subphylum Cheliceriformes - chelicerae, 2 body parts, 6 pair of appendages, no antennae

Class Arachnida - spiders, scorpions, ticks

Subphylum Uniramia - 1 pair of antennae, compound eyes

Class Diplopoda - millipedes

Class Chilopoda - centipedes

Class Insecta - 3 body parts, metamorphosis; insects

Subphylum Crustacea - 2 pair of antennae; lobsters , crabs, shrimp, barnacles, sowbugs

Phylum Ecinodermata - water vascular system, tube feet

Class Asteroidea - starfish

ClassOphiuroidea - brittle stars

Class Echinoidea - sea urchins

Class Crinoidea - sea lillies

Class Holothuroidea - sea cucumbers

Phylum Chordata

-interminate radial cleavage

-blastopore becomes mouth

-Possess 4 anatomical structures at some point in their lives:

1. Notochord - longitudinal, flexible rod located between gut and nerve cord (replaced by backbone in most vertebrates)

2. Dorsal, hollow nerve cord - develops from a plate of ectoderm that rolls into a tube located dorsal to notochord, develops into the central nervous system (brain and spinal cord)

3. Pharyngeal slits - allow water that enters digestive tracts to be expelled, functions as means of suspension-feeding or modified for gas exchange

4. Postanal tail - part of skeleton with muscles used for propulsive force in aquatic species

Subphylum Urochordata (tunicates) - sessile, marine, filter feeders

-adults retain only pharyngeal slits

Subphylum Cephalochordata (lancelets) - free-swimming, marine

-adults retain all 4 chordate characteristics

-somites - blocks of mesoderm tissue, evidence of segmentation

-paedogenesis - development of sexual maturity in larva

Evolution of vertebrate characteristics is associated with increased size and activity:

1. more cephalization in vertebrates

2. skeletal - jointed, flexible endoskeleton of bone, cartilage, or both consisting of:

1. vertebral column (backbone) - vertebral column of bony or cartilaginous vertebrae which replaces notochord. Surrounds and protects the nerve cord. Cranium (skull) encloses brain

-axial skeleton - skull and backbone

2. girdles - connect limbs to axial skeleton

-anterior pectoral girdle - connects arms or forelegs to axial skeleton

-posterior pelvic girdle - connects legs or hindlegs to axial skeleton

3. limbs - most have 2 pairs (fins, wings, legs, flippers)

-appendicular skeleton - girdles and limbs

-living endoskeleton of vertebrate - grows with organisms

-neural crest contributes to formation of certain skeletal elements

3. greater metabolic demands

-ATP through cellular respiration increases use of O_2, more efficient respiration

-closed circulatory systems, more consistent supply of O_2 to all tissues

-muscles in wall of digestive tract

7 classes of vertebrates:

-3 fish

-4 tetrapods

Amniotic egg enabled vertebrates to complete life cycle on land

-amniotes - reptiles, birds, and mammals

Specialized vertebrate body systems:

1. Integumentary - outer body covering, provides protection and helps regulate body temperature (skin, scales, feathers, fur)

2. skeletal - bones and cartilage of endoskeleton, support and locomotion, protection

3. Muscular - muscles, movement amd form walls of organs such as heart and stomach

4. Digestive - supplies energy by the breakdown of food, absorption of nutrients, (mouth, esophagus, stomach, intestines and accessory organs)

5. Excretory - waste removal, kidneys

6. Respiratory - exchange of gases between animals and environment, gills or lungs

7. Circulatory - transport system, ventral heart and closed pumping system

8. Immune (Lymphatic) - defense, cells and substances in blood that fight infection

9. Endocrine - regulate body processes, glands for production of hormones

10. Nervous - provide sensory perception and voluntary movement, brain, spinal cord, nerves, and sense organs

11. Reproductive - reproduction, male and female gametes

Lines of development in vertebrates:

1. Gills to lungs

2. Skeletal and muscular strengthening

3. Circulatory

-from 2 to 4 chambered heart

-single circulation (2 chambered heart) - atrium receives blood from body, goes to ventricle which pumps to gills to pick up oxygen, then to rest of body

-double circulation (4 chambered heart) - blood enters heart, pumped to lungs and picks up oxygen, returns to heart then pumped to rest of body

Vertebrate behavior:

Behavior - the way in which an organism responds to stimuli in its environment

2 types of behavior in vertebrates:

1. Inborn behavior (innate behavior) - inherited behavior

   -reflexes - simple, automatic reactions to stimuli, involuntary, protection devices

   -instincts - unlearned and involuntary actions that include

   a) self-preservation - example - fight or flee

   b) species preservation - example - nest building

2. Learned behavior - not inherited, flexible and can be changed

   a) conditioned response - learned response to specific stimuli (example - dog sitting down on command), taught by rewarding desired behavior

   b) intelligent behavior - involves problem solving, judgement, and decision making

Class Agnatha - jawless fishes

Class Chondrichthyes - sharks and rays

ClassOsteichthyes - bony fishes

Class Amphibia - frogs, toads, caecilians, salamanders

Class Reptilia - amniotic egg; ectothermic; lizards, snakes, turtles, crocodilians

Class Aves - endothermic; birds

Class Mammalia - hair or fur covering; mammary glands;teeth differentiation

-monotremes - egg laying mammals - platypuses and anteaters

-marsupials - pouched mammals - opossums, kagaroos, koalas

-placental - placenta

Order Chiroptera - bats, shrews

Order Lagomorpha - horses, rhinoceroses

Order Artiodactyla - deer, swine

Order Proboscidea - elephants

Order Sirenia - sea cows

Order Cetacea - porpoises, whales

Order Carnivora - cats, dogs, sea lions, seals

Order Rodentia - rats, squirrels, beavers

Order Primate - monkeys, apes, humans

LIST OF APPROVED EXPERIMENTS

1. Diffusion and Osmosis
2. Enzyme Catalysis
3. Mitosis and meiosis
4. Plant Pigments and Photosynthesis
5. Cell Respiration
6. Molecular Biology
7. Genetics of Organisms
8. Population Genetics and Evolution
9. Transpiration
10. Physiology of the Circulatory System
11. Animal Behavior
12. Dissolved Oxygen and Aquatic Primary Productivity

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