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**AP Biology Exam Review: Cell Signaling and Division (Unit 4)**

**Textbook Chapters:** 11 (Cell Communication), 12 (The Cell Cycle), 13 (Meiosis and Sexual Life Cycles)

**Topic Outline:**

1. There are three main steps in cell signaling

* Reception (target cell’s detection of a signal molecule)
* Transduction (conversion of the signal to a form that can bring about a particular cell response)
* Response (the specific cellular response to the signal molecule)

1. Reception

* Ligand (signal molecule) binds to receptor

1. Intracellular receptors (for hydrophobic molecules like steroids that can pass through the cell membrane)
2. Plasma membrane receptors (for hydrophilic molecules that cannot pass through the cell membrane)

Ex: G protein coupled receptor or receptor tyrosine kinase (see notes to recall how these work)

1. Tranduction

* Tranduction involves amplifying the signal (making it stronger) and converting it to a form the cell can respond to

1. Second messengers (ex: calcium ions – Ca2+ -- or cyclic AMP) carry the signal from the receptor and may be used to activate protein kinases or other key molecules in the transduction process… second messengers amplify the signal because multiple second messengers are created from one ligand received and these second messengers can activate multiple kinases
2. Phosphorylation cascade (protein kinases activate molecules by adding a phosphate group, these molecules then activate other molecules, and ultimately you activate a molecule that causes the specific cell response)
3. Response

* Regulating Synthesis of Proteins: Transduction may activate transcription factors that initiate transcription of particular genes in the nucleus (by enabling the binding of RNA polymerase to start creating mRNA from DNA)
* Regulating Activity of Proteins: ex: In the epiphrine pathway in liver cells that initiates breakdown of glycogen to produce blood glucose to fuel the fight or flight response, protein kinases activate the enzyme phosphorylase, which chops apart glycogen

***CC 3.D.3 -***

***a. Signaling begins with the recognition of a chemical messenger, a ligand, by a receptor protein.***

***Evidence of student learning is a demonstrated understanding of each of the following:***

***1. Different receptors recognize different chemical messengers, which can be peptides, small chemicals***

***or proteins, in a specific one-to-one relationship.***

***2. A receptor protein recognizes signal molecules, causing the receptor protein’s shape to change,***

***which initiates transduction of the signal.***

***To demonstrate understanding, make sure you can explain examples like:***

***● G-protein linked receptors***

***● Ligand-gated ion channels***

***● Receptor tyrosine kinases***

***b. Signal transduction is the process by which a signal is converted to a cellular response.***

***Evidence of student learning is a demonstrated understanding of each of the following:***

***1. Signaling cascades relay signals from receptors to cell targets, often amplifying the incoming signals,***

***with the result of appropriate responses by the cell.***

***2. Second messengers are often essential to the function of the cascade.***

***To demonstrate understanding, make sure you can explain examples like:***

***● Ligand-gated ion channels***

***● Second messengers, such as cyclic GMP, cyclic AMP calcium ions (Ca2+), and inositol***

***triphosphate (IP3)***

***3. Many signal transduction pathways include:***

***i. Protein modifications (an illustrative example could be how methylation changes the***

***signaling process)***

***ii. Phosphorylation cascades in which a series of protein kinases add a phosphate group to the***

***next protein in the cascade sequence***

1. The Cell Cycle

* Mitosis = creation of new body cells (somatic cells) with 46 chromosomes each (diploid cells / 2n = two sets of chromosomes
* Organization of DNA in eukaryotic cells = multiple linear chromosomes vs. organization of DNA in prokaryotic cells = single circular chromosome
* Interphase (normal life of the cell, 90% of cell’s life)… know what happens in the G1,S, and G2 phases
* Be able to describe the events that take place in the following steps of mitosis: prophase, prometaphase, metaphase, anaphase and telophase (+ cytokinesis, division of the cytoplasm by a cleavage furrow in animals or cell plate in plants)
* Be able to explain how/why eukaryotic cell division is different from binary fission
* **Vocabulary:** chromosome, sister chromatids, centromere, nuclear envelope, mitotic spindle, microtubules, kinetochore, centrioles / centrosome, metaphase plate, cleavage furrow, cell plate

1. Control of the Cell Cycle

* There are internal checkpoints that tell the cell to continue dividing or stop dividing
* Major checkpoints = G1 phase checkpoint (after G1 phase), G2 phase checkpoint, and M phase checkpoint
* If the cell does not receive the “go ahead” signal at the G1 checkpoint, it enters the “G0 phase,” a state of semi-dormancy where no cell division is occurring (ex: mature nerve cells)
* Example: if cyclin molecules bind to Cdk molecules (cyclin dependent kinases), they produce MPF (mitosis / maturation promoting factor)… enough MPF can allow the cell to pass the G2 checkpoint and enter mitosis… to bring mitosis to a close, MPF switches itself off by starting a process that degrades cyclin
* If checkpoints are normal… cells will show density-dependent inhibition (stop dividing when they are crowded) and anchorage dependency (must be attached to a substrate to divide)
* If cells divide two frequently, they will not show density-dependent inhibition or anchorage dependency 🡪 tumors (know the difference between benign and malignant tumors and be able to define metastasis)

1. Meiosis

* Cell division to create gametes (sex cells) with half the number of chromosomes (23) of a somatic cell (haploid cell / n = one set of chromosomes)
* Understand the difference between sexual vs. asexual reproduction
* There are 23 pairs of homologous chromosomes in a body cell (what are homologous chromosomes?) that divide during meiosis
* 22 pairs are autosomes and 1 pair consists of sex chromosomes (XX for females and XY for males)
* Fertilization = the fusion of haploid gametes (egg + sperm) to create a diploid zygote
* Meiosis includes two rounds of division to produce four daughter cells
* Be able to explain how Meiosis I is different from Meiosis II and describe what occurs in each of the stages of meiosis: Prophase I, Metaphase I, Anaphase I, Telophase I / Cytokinesis, Prophase II, Metaphase II, Anaphase II, Telophase II / Cytokinesis
* Explain what happens during crossing over. Be able to use the following vocab terms: synapsis, tetrad, chiasmata
* Describe the methods by which meiosis increases genetic variation in a population: crossing over, independent assortment, and random fertilization

***CC 3.A.1 –***

***a. Genetic information is transmitted from one generation to the next through DNA or RNA.***

***Evidence of student learning is a demonstrated understanding of each of the following:***

***1. Genetic information is stored in and passed to subsequent generations through DNA molecules and, in***

***some cases, RNA molecules.***

***2. Noneukaryotic organisms have circular chromosomes, while eukaryotic organisms have multiple linear***

***chromosomes, although in biology there are exceptions to this rule.***

***3. DNA replication ensures continuity of hereditary information.***

***b. Genetic information flows from a sequence of nucleotides in a gene to a sequence of amino acids in a***

***protein.***

***c. Phenotypes are determined through protein activities.***

***CC 3.A.2 –***

***a. The cell cycle is a complex set of stages that is highly regulated with checkpoints, which determine the***

***ultimate fate of the cell.***

***Evidence of student learning is a demonstrated understanding of each of the following:***

***1. Interphase consists of three phases: growth, synthesis of DNA, preparation for mitosis.***

***2. The cell cycle is directed by internal controls or checkpoints. Internal and external signals provide stop and-go signs at the checkpoints.***

***To demonstrate understanding, make sure you can explain examples like:***

* ***Mitosis-promoting factor (MPF)***
* ***Action of platelet-derived growth factor (PDGF)***

***3. Cancer results from disruptions in cell cycle control***

***4. Cyclins and cyclin-dependent kinases control the cell cycle.***

***5. Mitosis alternates with interphase in the cell cycle.***

***6. When a cell specializes, it often enters into a stage where it no longer divides, but it can reenter the***

***cell cycle when given appropriate cues. Nondividing cells may exit the cell cycle; or hold at a particular***

***stage in the cell cycle.***

***b. Mitosis passes a complete genome from the parent cell to daughter cells.***

***Evidence of student learning is a demonstrated understanding of each of the following:***

***1. Mitosis occurs after DNA replication.***

***2. Mitosis followed by cytokinesis produces two genetically identical daughter cells.***

***3. Mitosis plays a role in growth, repair, and asexual reproduction***

***4. Mitosis is a continuous process with observable structural features along the mitotic process. Evidence of student learning is demonstrated by knowing the order of the processes (replication, alignment, separation).***

***c. Meiosis, a reduction division, followed by fertilization ensures genetic diversity in sexually reproducing***

***organisms.***

***Evidence of student learning is a demonstrated understanding of each of the following:***

***1. Meiosis ensures that each gamete receives one complete haploid (1n) set of chromosomes.***

***2. During meiosis, homologous chromosomes are paired, with one homologue originating from the***

***maternal parent and the other from the paternal parent.***

***3. Orientation of the chromosome pairs is random with respect to the cell poles.***

***4. Separation of the homologous chromosomes ensures that each gamete receives a haploid (1n) set of***

***chromosomes composed of both maternal and paternal chromosomes.***

***5. During meiosis, homologous chromatids exchange genetic material via a process called “crossing over,”which increases genetic variation in the resultant gametes.***

***6. Fertilization involves the fusion of two gametes, increases genetic variation in populations by providing***

***for new combinations of genetic information in the zygote, and restores the diploid number of***

***chromosomes.***

**AP Biology Exam Review: Classical Genetics (Unit 5)**

**Textbook Chapters:** 13 (Meiosis and Sexual Life Cycles), 14 (Mendel and the Gene Idea)

**Helpful Videos and Animations:** *The links to these videos are posted on the class Wiki page*

1. [Bozeman Biology: Mendelian Genetics](https://www.youtube.com/watch?v=NWqgZUnJdAY&feature=BFa&list=PLFCE4D99C4124A27A)
2. [Bozeman Biology: Chromosomal Genetics](https://www.youtube.com/watch?v=rIe7mPXkYhs&list=PL7A750281106CD067&index=52&feature=plpp_video)
3. [Bozeman Biology: A Beginner's Guide To Punnett Squares](https://www.youtube.com/watch?v=Y1PCwxUDTl8&feature=BFa&list=PL7A750281106CD067)
4. [Bozeman Biology: Probability in Genetics - Multiplication and Addition Rules](https://www.youtube.com/watch?v=y4Ne9DXk_Jc&feature=BFa&list=PL7A750281106CD067)
5. [Bozeman Biology: Linked Genes](https://www.youtube.com/watch?v=-_UcDhzjOio&feature=BFa&list=PL7A750281106CD067)
6. [Bozeman Biology: The Genetics of Blood Types](https://www.youtube.com/watch?v=KXTF7WehgM8&feature=BFa&list=PL7A750281106CD067)

**Topic Outline:**

1. Mendel’s experiments

* Pea plants with distinct dominant vs. recessive traits
* Know what happens in the P 🡪 F1 🡪 F2 generations
* Mendel’s Laws

1. Law of Dominance
2. Law of Segregation (and explain how disorders caused by nondisjunction – ex. Trisomy 21 / Down Syndrome – are related to this law ; be able to define aneuploidy, monosomy, and trisomy)
3. Law of Independent Assortment
4. Basic Genetics Vocabulary

* Gene vs. allele
* Homozygous vs. heterozygous
* Genotype vs. Phenotype
* Monohybrid Cross vs. Dihybrid Cross
* Testcross

1. Setting up / analyzing genetic crosses with Punnett squares

* Know how to set up monohybrid and dihybrid crosses given information regarding parent genotypes and phenotypes and analyze offspring genotype / phenotype ratios
* Understand the rules of probability in Punnett Square analysis

1. Rule of Multiplication: when calculating the probability that two or more independent events will occur together in a specific combination, multiply the probabilities of each of the two events

For example, the probability of a coin landing face up two times in two flips is ½ X ½ = ¼

In genetics, if you cross two organisms with the genotypes AABbCc and AaBbCc, the probability of an offspring having the genotype AaBbcc is ½ X ½ X ¼ = 1/16

1. Rule of Addition: when calculating the probability that any of two or more mutually exclusive events will occur, you need to add together their individual probabilities. For example, if you are tossing a die, what is the probability that it will land on either the side with four spots or the side with five spots? (1/6 + 1/6 = 1/3)
2. Analyzing a pedigree of a human inherited condition

* Be able to describe the methods of fetal testing for inherited genetic conditions (amniocentesis and chorionic villi sampling)
* Be able to determine the type of inheritance shown in a pedigree (autosomal dominant, autosomal recessive, sex-linked dominant, and sex-linked recessive) Here are a couple hints:

1. If there are significantly more males with a condition than females, the trait is sex-linked (be able to explain why sex-linked recessive conditions are found more often in males)
2. With an autosomal trait, if a child has a trait but the parents don’t, the trait is recessive (both parents are carriers)

***CC 3.C.2: Biological systems have multiple processes that increase genetic variation.***

***a. The imperfect nature of DNA replication and repair increases variation.***

***b. Sexual reproduction in eukaryotes involving gamete formation, including crossingover***

***during meiosis and the random assortment of chromosomes during meiosis, and***

***fertilization serve to increase variation. Reproduction processes that increase genetic***

***variation are evolutionarily conserved and are shared by various organisms.***

***CC 3.A.3: The chromosomal basis of inheritance provides an understanding of the pattern of passage (transmission) of genes from parent to offspring.***

***a. Rules of probability can be applied to analyze passage of single gene traits from parent***

***to offspring.***

***b. Segregation and independent assortment of chromosomes result in genetic variation.***

***Evidence of student learning is a demonstrated understanding of each of the following:***

***1. Segregation and independent assortment can be applied to genes that are on***

***different chromosomes.***

***2. Genes that are adjacent and close to each other on the same chromosome tend to***

***move as a unit; the probability that they will segregate as a unit is a function of the***

***distance between them.***

***3. The pattern of inheritance (monohybrid, dihybrid, sex-linked, and genes linked on***

***the same homologous chromosome) can often be predicted from data that gives***

***the parent genotype/phenotype and/or the offspring phenotypes/genotypes.***

***c. Certain human genetic disorders can be attributed to the inheritance of single gene***

***traits or specific chromosomal changes, such as nondisjunction.***

***To demonstrate your understanding, make sure you can explain examples like:***

***● Sickle cell anemia***

***● Tay-Sachs disease***

***● Huntington’s disease***

***● X-linked color blindness***

***● Trisomy 21/Down syndrome***

***● Klinefelter’s syndrome***

***d. Many ethical, social and medical issues surround human genetic disorders.***

***To demonstrate your understanding, make sure you can explain examples like:***

***● Reproduction issues***

***● Civic issues such as ownership of genetic information, privacy, historical contexts,***

***etc.***

1. Non-Mendelian Patterns of Inheritance

* Explain how sex-linkage is different from autosomal patterns of inheritance and be able to set up a sex-linked Punnett square
* Codominance and Incomplete Dominance (be able to complete Punnett squares for these two patterns of inheritance)
* Multiple Alleles (blood type Punnett squares! Use the alleles i, IA, and IB)
* Pleiotropy
* Polygenic Inheritance
* Nonnuclear inheritance (traits determined by DNA in mitochondria or chloroplasts, not DNA in the nucleus)
* Traits influenced by the environment (ex: human height)

1. Linked Genes (found on the same chromosome and inherited together during cell division)

* Crossing over between homologous chromosomes during Prophase I of meiosis may separate linked genes onto different chromosomes. The frequency of recombination of linked genes due to crossing over increases if two genes are farther apart on the chromosome
* We can create a linkage map shown the location of genes on a chromosome. The distance between genes is measured in map units. 1 map unit = 1% recombination frequency 🡪 those genes are close together!

***CC 3.A.4: The inheritance pattern of many traits cannot be explained by simple Mendelian genetics.***

***a. Many traits are the product of multiple genes and/or physiological processes.***

***Evidence of student learning is a demonstrated understanding of the following:***

***1. Patterns of inheritance of many traits do not follow ratios predicted by Mendel’s***

***laws and can be identified by quantitative analysis, where observed phenotypic***

***ratios statistically differ from the predicted ratios.***

***b. Some traits are determined by genes on sex chromosomes.***

***To demonstrate your understanding, make sure you can explain examples like:***

***● Sex-linked genes reside on sex chromosomes (X in humans).***

***● In mammals and flies, the Y chromosome is very small and carries few genes.***

***● In mammals and flies, females are XX and males are XY; as such, X-linked recessive***

***traits are always expressed in males.***

***● Some traits are sex limited, and expression depends on the sex of the individual,***

***such as milk production in female mammals and pattern baldness in males.***

***c. Some traits result from nonnuclear inheritance.***

***Evidence of student learning is a demonstrated understanding of each of the following:***

***1. Chloroplasts and mitochondria are randomly assorted to gametes and daughter***

***cells; thus, traits determined by chloroplast and mitochondrial DNA do not follow***

***simple Mendelian rules.***

***2. In animals, mitochondrial DNA is transmitted by the egg and not by sperm; as***

***such, mitochondrial-determined traits are maternally inherited.***

***CC 4.C.2: Environmental factors influence the expression of the genotype in an organism.***

***a. Environmental factors influence many traits both directly and indirectly.***

***b. An organism’s adaptation to the local environment reflects a flexible response of its***

***genome.***

***To demonstrate your understanding, make sure you can explain examples like:***

***● Height and weight in humans***

***● Flower color based on soil pH***

***● Seasonal fur color in arctic animals***