Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Period: \_\_\_\_\_\_

**AP Biology Exam Review: Cell Division and Molecular Genetics (Unit 6 & 7)**

**Helpful Videos and Animations:**

1. Bozeman Science: The Cell Cycle, Mitosis, and Meiosis
2. Bozeman Science: DNA Replication
3. Bozeman Science: DNA and RNA - Part 1
4. Bozeman Science: DNA and RNA - Part 2
5. McGraw-Hill Animation: DNA Replication
6. Cold Spring Harbor Lab Animation: Griffith / Avery, McCarty, and Macleod Experiments
7. McGraw-Hill Animation: Hershey Chase Experiment
8. Bozeman Science: Transcription and Translation
9. McGraw-Hill Animation: Transcription
10. McGraw-Hill Animation: Translation
11. McGraw-Hill Animation: Intron Removal by Spliceosomes containing snRNP's (small nuclear riboproteins)

**Unit Vocabulary:**

-Genome

-Chromatin

-Histone Proteins / Histones

-Chromosome

-Chromatids / Sister Chromatids

-Centromeres

-Kinetochores

-Body Cells / Somatic Cells

-Sex Cells / Gametes

-Diploid

-Haploid

-The Cell Cycle

-Interphase (G1, S, and G2 phases)

-G0 phase

-M phase / Mitosis / Mitotic Phase

-Mitotic Spindle

-Microtubules

-Tubulin Subunits

-Centrosome

-Centrioles

-Prophase

-Prometaphase

-Metaphase

-Anaphase

-Telophase

-Cytokinesis

-Cleavage Furrow

-Cell Plate

-Parent Cell

-Daughter Cells

-Binary Fission

-Meiosis

-Karyotype

-Sex Chromosomes (X and Y)

-Autosomes

-Homologous Chromosomes

-Asexual Reproduction

-Budding

-Sexual Reproduction

-Gonads (ex: testes or ovaries in humans)

-Meiosis I vs. Meiosis II

-Synapsis

-Tetrad

-Chiasmata (singular chiasma)

-Crossing Over

-Segregation

-Independent Assortment

-Spermatogenesis

-Oogenesis

-Eggs / Ova (singular ovum)

-Polar Bodies

-Cell Cycle Checkpoints (the G1 phase checkpoint, the G2 phase checkpoint, and the M phase checkpoint)

-Cyclins

-CdK’s / Cyclin-Dependent Kinases

-MPF / Mitosis Promoting Factor / Maturation Promoting FActor

-Phosphorylation

-Growth Factors

-Density-Dependent Inhibition

-Anchorage Dependency

-Tumor (benign vs. malignant)

-Metastasis

-Griffith

-Avery / McCarty / Macleod

-Hershey / Chase

-Franklin / Wilkins

-Watson / Crick

-Double Helix

-Nucleotide (contains a phosphate group, 5 carbon / pentose sugar, and nitrogenous base)

-Nitrogenous Bases: Adenine, Guanine, Cytosine, Thymine (or Uracil in RNA)

-Chargaff

-Complementary Base Pairing

-Purines

-Pyrimidines

-Antiparallel

-5’ (five prime) End

-3’ (three prime) End

-DNA Replication

-Origin of Replication

-Replication Fork

-Helicase

-Free Nucleotides

-Primase

-Primer (made of RNA nucleotides)

-DNA Polymerase

-Leading Strand

-Lagging Strand

-Okazaki Fragments

-Ligase

-Semiconservative Model of DNA Replication vs. Conservative Model vs. Dispersive Model

-DNA Proofreading

-Nucleases

-Central Dogma of Molecular Biology (DNA → RNA → Protein)

-Ribose

-Deoxyribose

-Transcription

-Translation

-Types of RNA: messenger RNA (mRNA), transfer RNA (tRNA), ribosomal RNA (rRNA)

-Steps of Transcription: Initiation, Elongation, Termination

-RNA Polymerase

-Promoter Site

-Terminator Site

-mRNA Processing

-GTP Cap / 5’ (five prime) Cap

-Poly A Tail

-Introns

-Exons

-snRNP’s / Small Nuclear Riboproteins

-Spliceosome

-Splicing (the process of cutting out introns from the pre-mRNA)

-Ribozymes

-Steps of Translation: Initiation, Elongation, Termination

-Small Subunit of Ribosome

-Large Subunit of Ribosome

-A, P, and E sites in the Ribosome

-Codons

-Anticodons

-Amino Acid

-Peptide Bond

-Start Codon (AUG)

-Stop Codons (UAA, UAG, and UGA)

-Polypeptide

-Redundancy (in the genetic code)

-3rd Base “Wobble”

-Post-Translational Modifications

-Chaperonins

-Mutagens

-Carcinogens

-Point Mutations (3 Types: Silent, Missense, Nonsense)

-Frameshift Mutations (2 Types: Insertion, Deletion)

-Major Chromosomal Mutations (Large Deletion, Duplication, Inversion, Large Insertion, Translocation)

**Topic Outline:**

***Unit 6 Notes, Part 1 and 3 Notes: The Cell Cycle, Mitosis, and Regulation of Division***

1. The Cell Cycle

* Reason for division- as cells increase in volume, the surface area decreases and demand for material resources increases which limits cell size
* Smaller cells have a more favorable surface area-to-volume ratio for exchange of materials with the environment (diffusion, etc.). High SA:V ratio is favorable. Ex. 6:1 is better than 6:5
* 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)… : growth (G1), synthesis of DNA (S) and preparation for mitosis (G2).
* 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)

***Unit 6 Notes, Part 2: Meiosis***

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
* During meiosis, homologous chromosomes are paired (one from mom and one from dad) and line up in the center of the cell randomly. The homologues are pulled apart and separated in meiosis I. A second division occurs in which the duplicated chromosomes are pulled apart.
* Variation occurs in gametes during “crossing over,” and fertilization because of all possible combinations of homologous chromosomes aligning during metaphase I (independent assortment)

***Unit 7 Notes, Part 1: DNA***

1. DNA History

* Be able to describe the experiments leading to the discovery of DNA as the cell’s genetic material. Key scientists include

1. Franklin, Watson, Crick, Wilkins
2. Griffith
3. Hershey / Chase
4. Avery-MacLeod-McCarty
5. Structure of DNA

* Deoxyribose nucleic acid
* Double helix (two twisted stsrands) made of nucleotides (monomers)
* Nucleotide = phosphate + 5C deoxyribose sugar + nitrogen base
* Antiparallel strands- one runs 3’ to 5’ the other runs 5’ to 3’,sides of phosphates and sugars
* (backbone), rungs of paired bases with hydrogen bonds in between
* Purines (adenine,guanine; double rings) pair with Pyrimidines (cytosine, uracil, thymine; single ring)
* A - T- double H bond
* C – G- triple H bond

1. Location of DNA

* In eukaryotes DNA is found in nucleus on multiple linear chromosomes (a chromosome IS a strand of DNA with proteins etc. associated).
* In prokaryotes DNA is not in a nucleus and is usually a single circular chromosome
* Prokaryotes, viruses, and eukaryotes (yeast) can contain plasmids (small extra-chromosomal DNA that is double stranded DNA)

1. DNA replication

* Process of making exact copies of DNA (i.e. for mitosis or meiosis)
* Process is semi conservative (original strand is copied)
* Steps

1. Enzyme (helicase) unzip strands by breaking hydrogen bonds
2. “Spare” nucleotides are added bidirectionally to bond complementarily with use of DNA polymerases (DNA pol)
3. DNA pol only can add to the 3’ to 5’ side and new DNA is made in the 5’ to 3’direction
4. Replication bubbles open up and a replication fork is created because bubble is in half and it has one side 3/5 and one 5/3
5. RNA primers must be laid down to start process (RNA primase makes primers)
6. Leading strand makes DNA continuously (3/5)
7. Lagging strand makes DNA discontinuously (5/3), Okazaki fragments
8. Lagging strand requires enzyme (ligase) to fuse fragments

***Unit 7 Notes, Part 2: From Gene to Protein***

1. RNA

* Ribonucleic acid
* Single stranded, different sugar called ribose, different base called uracil INSTEAD of thymine
* Base pair rules in RNA, A-U and C-G
* messenger RNA or mRNA carries information from DNA to the ribosome
* transfer RNA or tRNA bind amino acids and are used in translation at ribosome

1. Transcription

* making mRNA in nucleus
* enzyme RNA pol reads the DNA in 3’ to 5’ direction and synthesizes complementary mRNA
* Ex. 3’ to 5’ DNA is ATG CAT then the 5’ to 3’ mRNA made will be UAC GUA
* Steps

1. Promoter is where RNA pol binds and begins
2. Elongation (adding of RNA nucleotides- does not stay attached to DNA)
3. Termination, ends when RNA pol reaches a termination sequence
4. mRNA editing

* introns spliced out (cut out) using spliceosomes (snRNP’s)
* add polyA tail to 3’
* add GTP cap to 5’
* each 3 are called a codon
* go to ribosome (free or in rough ER)

1. Translation

* mRNA code is read and matched with tRNA (brings amino acids) to construct a polypeptide using the ribosome
* Ex. mRNA codon is AAA then tRNA anticodon will be UUU and will have a corresponding amino acid for that codon of mRNA
* 3 steps: Initiation, Elongation, Termination (see notes)
* If in ER then: polypeptide is released into ER, then to Golgi complex, vesicle to cell membrane, then exocytosis (may be given signals for exit/destination)
* Free ribosomes typically make products for the cell and are not exported

1. Mutations and Increasing Genetic Diversity

* Changes to the DNA sequence are not all harmful…some can increase genetic variability 🡪 more possible forms of traits so that not all organisms can be killed off by any one factor (ex: a disease that kills all tall people)
* They can be spontaneous errors in replication or they can be caused by mutagens (environmental factors like radiation, chemicals, cigarette smoke, etc.)
* If a mutagen causes changes in genes that regulate the cell cycle / cell division it is considered a carcinogen (a cancer-causing factor)
* Some mutations are neutral (happen in introns that do not code for proteins)
* Some mutations are harmful (change protein function in a negative way)
* Types of Mutations:

1. Point mutation: change in one base pair of a gene (substitution: replace one base with another)
2. Silent – changes one base, but codes for the same amino acid (due to redundancy)
3. Missense – codes for another amino acid (changes protein sequence and usually function)

Example: sickle cell disease… one T substituted for A in the gene coding for hemoglobin protein

* Nonsense – code changes to a stop codon (makes a nonfunctional protein that is terminated early)
* Frameshift mutation: the mutation effects all nucleotides / codon groupings farther along the DNA / RNA code
* Insertion – adding extra nucleotides (causes a frameshift if you are not adding exactly three extra bases)
* Deletion – removing nucleotides (causes a frameshift if you are not removing exactly three bases)

Example: O blood type allele involves a deletion in the A blood type code

***Unit 7 Part 3 is in the Gene Regulation and Biotechnology Packet (Unit 8)***

**Lab Review**

***Cell Division***

|  |  |
| --- | --- |
| Background Information | In this lab, you will be investigating the effect of lectin (a molecule that induces mitosis) in onion root tips. You will stain samples of onion root tips to view the DNA in the cells and you will count the frequency of cells in interphase vs. mitosis based on the appearance of the DNA in the cells.  This is what the DNA will look like in cells in interphase vs. various stages of mitosis: |
| Hypothesis | If onion root tips are exposed to lectin, then they will have a higher percentage of cells undergoing mitosis than root tips not exposed to lectin. |
| Methods | Basics: You will grow one group of onion root tips in soil that contains lectin and one group of onion root tips in soil that contains only distilled water.  **Independent** Variable: the presence of lectin in the soil  **Dependent** Variable: percentage of cells in interphase vs. mitosis  **Control Group** (group not exposed to the independent variable): the onion root tips grown in soil that contains only distilled water  **Experimental Groups** (groups exposed to varying degrees of the independent variable): the onion root tips grown in soil that contains lectin  **Constants** (to make sure that any differences between the control group and experimental groups are due to the independent variable alone): soil, type of onion, humidity, temperature, etc.  **Repeated Trials**: Need to have 3-5 onion root tips in each treatment group to ensure accuracy of data |
| Data Collection & Organization | You will record your data in a chart similar to the one given below… |
| Data Analysis | You will compare the mean percentage of onion root cells in interphase vs. mitosis across 3-5 trials in both of the treatment groups to either support or refute the hypothesis. |

**Practice “Thinking” Questions**

1. Refer to the figure to the right.
2. What process is being shown in this picture?
3. What type of organism are these cells from? How do you know?
4. Identify a numbered cell for each of the four major stages of mitosis.
5. In what stage are most of the cells in this image? What does this indicate about the amount of time spent in each phase of the cell cycle?
6. Paclitaxel is a chemotherapy drug used to treat a variety of cancers. Paclitaxel inhibits both assembly and disassembly of microtubules.
7. Which phases in the cell cycle are affected by Paclitaxel? How does this drug inhibit the growth of cancer?
8. Paclitaxel affects not only cancer cells, but normal cells as well. Would the effects of Paclitaxel be seen first in organs that have quickly dividing cells (like the intestine and hair follicles) or in organs that have slow or nondividing cells (like muscles and the nervous system). Justify your reasoning
9. Two students debate about proteins that regulate the cell cycle. One argues that MPF triggers the production of cyclin, while the other argues that cyclin triggers the production of MPF.
10. Based on the figure to the right, which statement is correct and why?
11. Propose a possible function of MPF, based on when it is produced in the cell cycle.
12. Compare the two DNA sequences shown below. Transcribe them into mRNA and translate them into an amino acid sequence.

GTG CAC CTC ACA CCA GAG GAG (Normal Hemoglobin)

mRNA 🡪

amino acids 🡪

GTG CAC CAC ACA CCA GTG GAG (Sickle Cell Hemoglobin)

mRNA 🡪

amino acids 🡪

1. Circle any differences there are in the DNA, RNA and amino acid sequences that might exist between these two sequences.
2. Identify the type of mutation that is represented AND EXPLAIN, IN DETAIL, what effect this would have on the protein/pigment.
3. In prokaryotic cells, translation begins before transcription is finished. Give two reasons why this would not be possible in eukaryotic cells.
4. When DNA replicates, each strand of the original DNA molecule is used as a template for the synthesis of a second, complementary strand. Compare and contrast the replication of the two new strands, **listing** and **explaining** at least one similarity and one difference in the methods of synthesis. You may draw a diagram to help answer the question, but be sure to explain your diagram in your answer.

**Practice Short Response Questions**

1. Meiosis reduces chromosome number and rearranges genetic information. **Explain** how the reduction and rearrangement are accomplished in meiosis.