

Exam II Study Guide

Chapter 8: Cellular Reproduction

- Know the eukaryotic **cell cycle**—G₁, S (synthesis), G₂, M (mitosis)—the stages of **mitosis** (prophase, metaphase, anaphase, and telophase), interphase (G₁, S, and G₂), and cytokinesis.
- Asexual vs. sexual reproduction
- Know the difference between **chromatin**, **chromosome**, and **sister chromatid**.
- Understand the different levels of DNA structure and packing—from the double helix up to the condensed chromosomes of mitotic cells.
- Understand the difference between mitotic and meiotic divisions.
- Know the terms **ploidy**, **haploid**, **diploid**, and **tetraploid**.
- Understand the human lifecycle—**gametes** (sperm and egg) meet in **fertilization** to form a **zygote** which develops into an fetus which develops into an adult human that produces gametes.
- Understand the origins of **genetic diversity** in sexual reproduction: **crossing over** (recombination) between homologous chromosomes and random arrangement of those homologous chromosomes on the metaphase plate during the first meiotic division.
- Know the mechanism by which meiosis can go wrong—**nondisjunction**.

Chapter 9: Mendelian Genetics

- Who was Gregor Mendel? Know the history.
- Understand self- and cross-fertilization and what **P**, **F₁**, and **F₂ generations** are in a cross.
- Understand the terms **wild-type**, **allele**, **genotype**, **phenotype**, **dominant** and **recessive**.
- Know how to work out **monohybrid** and **dihybrid crosses** with a **Punnett square!**
- Understand Mendel's **Principle of Segregation** and **Principle of Independent Assortment!**
- Know how to do a **testcross** to figure out genotype from phenotype.
- Understand the basic concept of **probability** and the **rule of multiplication**.
- Know what a **pedigree** looks like.
- Understand the terms **homologous chromosomes**, **autosome**, and **sex chromosome**.
- Note the exceptions to Mendel's rules: **incomplete dominance**, **codominance**, **pleiotropy**, and **polygenic inheritance**.
- Understand the **chromosome theory of inheritance** and how it explains all of the above.
- Think about **gene linkage** (when genes are on the *same* chromosome) and how that might affect assortment of traits.

Chapter 10: Molecular Biology of the Gene

- **Review DNA and RNA structure**, nucleotides (sugar, phosphate, and nitrogen base), what parts of the nucleotides make up the backbone of DNA (covalent bonds between the sugars and phosphates) and what part of the nucleotides bring the two strands of DNA together (hydrogen bonds between the nitrogen bases)
- Who are/were **Watson, Crick, and Franklin?** Know about their contributions to the discovery of the **double helix**.

- **DNA Replication:** What are the ingredients? What are the template and the product? Where does it happen? What enzyme/molecular machine is involved?
- ‘Central dogma’ of molecular biology (how genotype translates to phenotype): the flow of information goes from **DNA to RNA to protein**.
- **Transcription:** What are the ingredients? What are the template and the product? Where does it happen? What enzyme/molecular machine is involved? Know the three steps: **Initiation** (at the promoter), **Elongation**, and **Termination**.
- **RNA Processing:** What happens to RNA molecules after transcription in eukaryotic cells? **Cap and tail, splicing of exons and introns**.
- **Translation:** What are the ingredients? What are the template and the product? Where does it happen? What enzyme/molecular machine is involved? Know the three steps here too: Initiation (at the **start codon**), Elongation, and Termination (at the **stop codon**). Be able to describe *how* translation works (the steps of codon recognition, peptide bond formation, and translocation).
- Be familiar with the terms **codon, anticodon** and understand how the nucleotide language of DNA and RNA is translated to the amino acid language of proteins in the flow of genetic information in the cell (i.e. the **genetic code**—certain codons are specifically associated with certain amino acids; the codons on mRNA are bound by the anticodons on a tRNA carrying a specific amino acid).
- Know the three different kinds of RNA and where they function in the cell.
- Understand the different kinds of **mutations** and the possible result of each (base change, insertion, deletion).
- Be able to discuss the different kinds of **viruses** and how they work in their target cells.

Chapter 11: Regulation of Gene Expression

- How are all the different cell types in our bodies really *different* if they have the *same* genome? **Gene expression** patterns differ with each cell type.
- What are the **cell fate choices** a cell has (each driven by a different kind of signal)?
- How are genes “regulated,” turned on and off, in these different processes?
- Gene expression can be regulated on many levels in eukaryotic cells, from where the gene is located in the nucleus to how it is packed in the chromatin, to what proteins are binding to the control sequences and when they bind.
- Start with a simple and elegant system like the lac operon in bacteria (know the terms **operon** and **control sequence** (examples of control sequences are **promoter** and operator): (1) When there isn’t any lactose around, the lac repressor binds to the **operator** sequence on the DNA and prevents RNA Polymerase from seeing and binding to the promoter. (2) When lactose is present in the environment and the cell, it binds to the lac repressor and prevents the repressor from binding the operator. This frees up the promoter for RNA Polymerase to bind and initiate transcription of the entire operon. So, lactose directly regulates expression of the enzymes that breakdown lactose!
- One example of gene regulation on the large scale is **X chromosome inactivation**. This happens specifically in female mammals to balance the level of X chromosome genes between males and females—in each **somatic cell** of the female, one of the X chromosomes is packed in a special way to prevent RNA Polymerase from accessing it.

- All of the processes that we discussed that are needed to “express” a gene can be regulated to either increase or decrease the expression of that gene, including **transcription, RNA processing, and translation**.
- Regulating transcription: regulatory proteins called **transcription factors** (which can be activators or repressors) bind to control sequences around eukaryotic genes (such as the **promoter, enhancers or silencers**). The activators help RNA Polymerase to bind to the promoter and the repressors can prevent RNA Polymerase from binding to the promoter (so this would technically be regulation of the *initiation* of transcription). It is the balance of activators and repressors that are acting on a gene that really determine whether it will be expressed or not.
- RNA processing can also be regulated—on example of this is **alternative splicing**, which involves the selective splicing together of certain exons but not all exons to give different mature mRNA molecules (which will of course code for slightly different proteins).
- **Translation** is regulated much in the same way that transcription is regulated—there are factors which can bind to the RNA and alter ribosome binding, for example, and factors that can affect the rate of elongation. The resulting protein can also be processed by enzymes to make it a mature, functional protein (another step which can be controlled).
- **Gene expression** can also be regulated through the **stability** of the different working products, mRNA and protein. mRNA/protein molecules that are not that stable will be quickly degraded in the cell, making the “expression” of that gene very transient.
- **Cell signaling** is what ultimately drives changes in gene expression—this can be communication between adjacent cells or a distant cell sending out chemical signals to, for example, recruit inflammatory cells to a site of injury. These signaling events are what drive development—from the zygote to the adult organism.
- Understand the **genetic basis of cancer** (think about how changes in DNA sequence or whole chromosomes can change a cell and know what **oncogenes** and **tumor suppressors** are).
- Review **stem cells** and **cloning**. Know the different types of stem cells (embryonic versus somatic/adult stem cells) and the different kinds of ‘cloning’ (therapeutic versus reproductive).

Chapter 12: DNA Technology

- Know what ‘biotechnology’ is and how **genetically modified organisms** are generated
- Understand how **bacteria** and **plasmids** are used in recombinant DNA technology
- Be able to describe the **techniques** covered in this chapter: (1) using **restriction enzymes** for making recombinant DNA molecules and **genomic libraries** or in restriction fragment length polymorphism (**RFLP**) analysis, also known as DNA fingerprinting, (2) using radiolabeled DNA **probes** to screen a library (i.e. find the bacterial colony, or clone, with the plasmid containing your gene of interest), (3) making a copy of a gene using eukaryotic mRNA and **reverse transcriptase**, (4) DNA amplification by **polymerase chain reaction**, and (5) separation of DNA fragments by **gel electrophoresis**.
- Know the many different applications of DNA technology: (1) making genetically modified organisms for producing medicine or for increasing crop yield in agriculture, (2) gene therapy, (3) DNA fingerprinting (and the various applications thereof), and (4) genomics (sequencing and analyzing genomes of various species to learn about disease and evolution).
- Know a little bit about the **history** of DNA technology... What was the first medicine to be approved by the FDA that came from a genetically modified organism? What was the name of one of the first biotechnology companies to use recombinant DNA technology?