Chapter 16 The Molecular Basis of Inheritance

Make sure to associate DNA replication with the cell cycle (G1, S, G2, M). DNA replication occurs during S phase as a cell is preparing to divide.

16.1 DNA is the genetic material

I am going to cut some of the content from this chapter in order to make up some time. The historical topics described in red will not be represented on the unit test, but I recommend that you familiarize yourself with them if you are aiming for a 4 or 5 on the AP exam. Please see me during X block to check your understanding if you wish.

History

- Explain how Grifitth's and Avery's experiments contributed to the understanding that DNA (not RNA, not protein) is the hereditary material
- Explain the term **transformation** in the context of the experiment shown in Fig. 16.2
- Explain how the Hershey-Chase experiment backed up Avery's conclusion that DNA (not protein) is the hereditary material

Structure

- Go back to chapter 5 and review the basic structure of nucleic acids
- Be able to recognize the monomers (nulceotides) in a single strand of DNA
- Be able to distinguish between purines and pyrimidines
- Go back to chapter 5 and review dehydration synthesis
- Explain the meaning of the phrase "the 5' phosphate of one nucleotide bonds to the 3' hydroxyl of a neighboring nucleotide" in the context of assembling nucleotides into DNA
- Explain the meaning of the term "antiparallel" in terms of the double-stranded structure of DNA
- Identify which components of the nucleotide structure participate in hydrogen bonds

16.2 Many proteins work together in DNA replication and repair

History

- Explain how the Meselson and Stahl experiment supports the semi-conservative model for DNA replication

Mechanism

This is a dynamic process. It is very important for you to use media that represents DNA replication in action as part of your study material. I recommend that you listen to narration. Then mute the volume and try to narrate the process yourself. Replay a third time with narration to check your understanding.

- Explain the meaning of the term "semi-conservative" as it applies to DNA replication
- Explain the relationship between a replication bubble and a replication fork

- Explain why one side of the replication fork is copied continuously and the other side of the replication fork is copied in short fragments which must later be linked together

Mutations

- Know that the cell does its best to preserve the accuracy of the genetic code: most errors in DNA replication are detected and corrected, most damage to DNA is recognized and repaired; those few changes that do persist are called mutations
- Somatic cell mutations that alter progression through the cell cycle may result in cancer
- Germ cell mutations may be passed on during meiosis and appear in the next generation

Eukaryote Telomeres

- Due to the dependence of DNA polymerase on an RNA primer to begin replication, the 5' end of a newly synthesized DNA strand will necessarily be a bit shorter than the template it copied Fig 16.20
- Explain how the structure of telomeres determines the function of somatic cells will not be hindered by telomere shortening
- Which type of cell must regenerate its telomeres? Why?
- Prokaryotes do not have the problem of telomere shortening. Why?

<u>16.3 Chromosome Structure</u>

- It is not necessary to know the relative diameters of each stage of DNA packaging
- Describe the general role of histones
- Describe the relationship between chromatin and chromosomes
- Distinguish between heterochromatin and euchromatin

Chapter 17 From Gene to Protein

Avoid this common pitfall: We study transcription and translation after we study DNA replication. This does not mean that all three processes occur in sequence in a cell.

Transcription and translation are associated with gene expression, that is, interpreting the DNA code represented in a sequence of A, C, T, and G in order to assemble amino acids into polypeptides.

When you are done reading Ch. 17, you should be able to talk your way through figure 17.26. Use this picture to check your understandings along the way.

Use the BioFlix animation for Transcription and Translation (masteringbiology.com) to see these processes in motion. Play the video on mute and practice narrating each process in your own words.

<u>17.1 Genes specify proteins</u>

- The experiment described in Fig 17.2 is a classic. If you are shooting for a 4 or 5 on the AP exam, read it closely. Be prepared to interpret a diagram such as the one shown next to the title "Results." I will not be discussing this in class, but I am happy to go over it with you during X block.
- Start reading closely when you get to the section, "Basic Principles of Transcription and Translation
- All of the bold terms are critical
- It is not necessry to memorize any codons (fig 17.5), but it is nice to know that AUG is the "start" codon in addition to representing the amino acid methionine
- What does it mean to say that there is redundancy in the genetic code?
- In which position of the codon does this redundancy appear (1st, 2nd, or 3rd, base?)
- Go back and review Fig 5.16. Your text refers to the N-terminus (amino end) and the C-terminus (carboxyl end) of the growing polypeptide chain. This is referring to the structure of the amino acids
- Do you remember how peptide bonds form? Review Fig 5.17

<u>17.2 Transcription is the DNA-directed synthesis of RNA</u>

- All of the bold terms are critical
- Be able to use the terms to talk your way through Fig 17.8 and 17.9
- Notice there is a subtle difference between eukaryotes and prokaryotes at the termination stage: it is sufficient to know that in both cases a specific sequence of the newly synthesized RNA signals the cell to stop transcription. If you can manage to know the difference, great. If not, it is sufficient to know that the mechanisms do vary from one another.

<u>17.3 Eukaryotes modify mRNA</u>

- Be able to describe 3 examples of RNA processing: 5'cap, poly A tail, and spicing
- For splicing: distinguish between introns and exons, describe the structure and function of the spliceosome

<u>17.4 Translation</u>

- You have already encountered mRNA and snRNA. Now you will see rRNA and tRNA. Organize your understanding of this family of molecules in terms of their functions
- Associate codon with mRNA
- Associate anti-codon with tRNA
- You now know 3 ways in which cells make use of complementary base pairing. What are they?
- We use highly schematic diagram to represent the molecules involved in translation. Look closely at fig 17.15, 16, and 17 in order to relate the schematic structure to the 3-D molecules that they represent.
- tRNA is said to be "charged" when it is carrying the amino acid corresponding to its anticodon
- Be able to recognize the term "aminoacyl-tRNA synthetase" and describe its function. If

you can remember the name of the enzyme, too, that's great but not necessary
- Relate "wobble" to the redundancy of the genetic code
- It's good to know that there exist subtle differences in the process of translation between eukaryotes and prokaryotes--it is not critical to be able to state them

Initiation Fig 17.18
- the start codon is situated near the 5' end of the mRNA
- the small ribosomal subunit and the initiator tRNA bind to the mRNA
- the large ribosomal subunit along with miscellaneous protein "initiation factors" comlete the initiation complex
- notice this is the only time you will see aa-tRNA in the P site of the large ribosomal subunit

Elongation Fig 17.19
- incoming aa-tRNA delivers the next amino acid into the A site
- the large ribosomal subunit catalyzes formation of covalent bond between the incoming aa and the growing polypeptide chain
- the ribosome shifts 3 bases toward the 3' end of the mRNA, exposing an empty A site and releasing the "uncharged" tRNA from the E site

Termination Fig 17.20
- When a "stop" codon is positioned in the A site, a protein release factor enters the A site
- the polypeptide is released from the adjacent tRNA
- the transcriptional machinery is disassembled and released from the mRNA
- ultimately, when enough protein has accumulated in the cell, the mRNA will be broken down and the nucleotide subunits will be recycled

Completing and Targeting the Functional Protein
- For a reminder of the diverse functions of proteins, review figure 5.15
- Additionally, review the levels of protein structure, figure 5.20
- Read this section of the text closely and make connections to what you learned previously about cell membrane structure and the structure/function of eukaryote organelles
- For figure 17.22, it's okay if you don't remember the term "signal recognition particle," but keep in mind the fact that the cell has a system to deliver newly synthesized proteins to the appropriate location in the cell

<u>17.5 Mutation</u>
- You are responsible for distinguishing between all of the types of mutation summarized in Fig 17.24

<u>17.6 Gene expression among the domains of life; gene concept</u>
- Read for the "big picture"--not a lot of nitty gritty detail here

Ch 18 Regulation of Gene Expression

18.1 Regulating Prokaryotic Gene Expression

(consult the handout on “operons” distributed in class)--I have also shared it electronically via Google Docs

18.2 Regulating Eukaryotic Gene Expression

This is a bear. Ground yourself in Fig 18.6. It is more important to be able to *recognize* examples of control of gene expression than to be able to list all of them by rote memory. Organize your thinking in these categories:

Pre Transcriptional

- chromatin packing: heterochromatin vs. euchromatin
- histone modification: acetylation or methylation
- DNA methylation

Transcriptional

- presence of transcription factors
- presence of activators or repressors
- efficiency of combinatorial control
- efficiency of co-ordinate control

Post Transcriptional

- consequence of alternative splicing
- timing of mRNA degredation

Translational

- presence of initiation factors

Post Translational

- chemical modification of polypeptide to activate
- transport protein to target destination (or sequestration in storage organelle)
- degradation of protein by proteasomes

18.3 Non-coding RNAs

- the basic idea here is that you don’t want to leave this course thinking that mRNA, rRNA, and tRNA are the only functional products of transcription
- ncRNA (non coding RNA) are diverse in function
    - miRNA (micro RNA) and siRNA (small interfering RNA) cooperate with proteins to regulate translation of specific mRNA
    - RNAi is an experimental technique that introduces double-stranded RNA into a cell and results in degredation of complementary mRNA
    - piRNA (piwi-RNA...for real?)
        - may be responsible for inducing heterochromatin formation and quieting genes carried by transposons
        - may be responsible for resetting methylation patterns associated with genome imprinting during gamete formation

18.4 A program of differential gene expression

If you are aiming for a 4 or a 5 on the AP exam, I suggest you read this section of Chapter 18 and the section from chapter 47 below. I am not holding you responsible for this content in class.

- To the best you can, read for a general sense of how development progresses from a single totipotent cell (the zygote) to a multicellular organism consisting of highly differentiated cells
- Note that specific genes must be expressed at precisely the right developmental stage by specific cells in order for development to proceed normally
- Be aware that the mechanism for induction involves cell signalling (see Fig 18.17b). Relate this back to the general steps of cell signalling given in Ch 11(see Fig 11.6).

47.3 Cytoplasmic determinants and inductive signals

I think this topic matches in with our curriculum best in connection with regulation of gene expression. To my understanding, other topics in chapter 47 are not within the scope of the AP exam. I am not holding you responsible for this content in class.

- distinguish between totipotent and differentiated
- describe an example of induction: dorsal lip in embyrogenesis or ZPA in pattern formation of the vertebrate limb

18.5 Cancer results from genetic changes

You can read most of this for sense, rather than explicit detail (exceptions below).

- Distinguish between proto-oncogenes and oncogenes
- Contrast oncogenes and tumor suppressor genes. Be able to generally describe how each may affect cell cycle in such a way that results in cancer as in Fig 18.24(c)
- The remainder of this section is a good read for general knowledge. You are not responsible additional details