AP Biology
Unit 6 - Gene Expression and Regulation

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1. DNA and RNA structure:

- nucleic acid: DNA and RNA
- nucleotide: nucleotide monomer; consists of phosphate group, nitrogenous base, and five carbon sugar
    - Five types of nitrogenous bases:
        - Adenine:
        - Thymine:
        - Cytosine:
        - Guanine:
        - Uracil:
    - Purines: A and G, Nitrogenous bases with two organic rings
    - Pyrimidines: C and T, Nitrogenous base with a single organic ring
- Complementary base: A base that is capable of bonding with another base
    - G binds to C, A binds to T (in DNA), or A binds to U (In RNA)
- Sugar-phosphate backbone: A string of alternating phosphate groups and sugars that form the structural support for a strand of DNA
- Double helix: the overall shape of a DNA molecule, produced by DNA's two strands
    - RNA has only one strand

2. **Replication**:

- DNA Replication: DNA molecule is copied
- Famous Figures
  - Virus: infects a cell and takes over the cell's metabolic machinery
    - Hershey and Chase: Concluded that phage DNA entered bacterial host cells, but phage proteins did not, so DNA functions as the genetic material
  - Chargaff's Law: the base composition of DNA varies between species and for each species, the percentages of A and T bases are roughly equal to the percentages of the G and C bases
  - Rosalind Franklin: accomplished X-ray crystallographer that discovered the double helix of DNA
  - Watson and Crick: Came up with the structural model of DNA
- Antiparallel: strands run in opposite directions
- Semiconservative Model: copied DNA strand is half parent strand, half newly synthesized strand
- Replication Fork:region at which the DNA is being unwound from the helical structure
  - Helicases: enzymes unwind the DNA strands
  - Single Strand Binding Proteins: Bind to the unpaired DNA strands keeping them from repairing
  - Topoisomerase: help reduce the twisting and tangling while the DNA strand is being unwound
- Primer: short stretch of RNA placed on the unwound parental DNA strands that acts as a template strand
  - Synthesized by primase
- DNA polymerases: Enzyme that catalyze the synthesis of new DNA by adding nucleotides to a preexisting chain
- Leading strand: strand that is synthesized continuously
- Lagging Strand: synthesized discontinuously
- Okazaki fragments: Series of segments on the lagging strand

- DNA Ligase: joins the sugar phosphate backbones of all the Okazaki fragments into a continuous DNA strand
- DNA pol III: primary enzyme that works to synthesize the new strand
- DNA pol I: removes primers and replaces them with the proper nucleotides
- Nuclease: DNA cutting enzyme that cuts out the damaged parts of the strand and fills the space with nucleotides using the undamaged strand as a template
- Telomerase: enzyme that helps keep the length of chromosomes; aids in replacing the DNA shortening that happens during duplication
- Histones: responsible for DNA packing in chromatin

3. **Transcription and RNA Processing:**

- Transcription: starts when RNA polymerase binds to the promoter region of a gene
    - Ends with termination
    - Produces RNA
        - mRNA (messenger RNA) copy of DNA instructions
        - rRNA (ribosomal RNA) helps make ribosomes
        - tRNA (transfer RNA) reads the message coded by mRNA to the ribosomes (decoder)
    - Occurs in nucleus
- Ribose:five-carbon-sugar for RNA
- Codon: 3 nucleotide code on mRNA that codes for a specific amino acid sequence
- AUG CGU UAG Transcribes to the following triplet TAC GCA ATC
- Introns: segments of DNA that do not contain genes
- Exons: segments of DNA that contain genes
- Splicing: removal of introns and exons are put together

4. **Translation: (These terms were mentioned or defined before):**

- Produces a polypeptide chain
- tRNA: brings the amino acid to the ribosome, where it meets rRNA. Carries the anticodon sequence to mRNA's codon, helping it bring the correct amino acid
    - Anticodon: the 3 nucleotide sequence that is complementary to the codon

5. **<u>Regulation of Gene Expression:</u>**

- Operon: A segment of DNA that includes a series of structural genes and the control elements regulating the transcription of those genes.
- Promoter: where the RNA polymerase binds to begin transcription
- Operator: where a repressor protein binds to prevent the initial binding of RNA polymerase to the promoter
- Feedback Inhibition: often a way to regulate transcription, but is very wasteful because it produces a lot of product that is not necessary
- Repressible Operons
  - Best modeled by the trp-operon, or the operon responsible for the production of tryptophan.
  - The operon is constantly "on", the repressor protein is unable to bind to the operator and the RNA polymerase is able to synthesize mRNA, leading to the production of proteins that produce tryptophan.
  - An excess of tryptophan, however, assists in the binding of the operon's repressor protein to the operator region. Tryptophan is essentially a feedback inhibitor.
  - The operon is repressible: constantly "on", but can be turned off

- Inducible Operon
  - Opposite to repressible operons; best modeled by the lac-operon
  - The operon is constantly "off": the repressor protein is attached to the operator region and RNA polymerase cannot bind to produce mRNA.
  - The presence of lactose in the environment, however, is converted into allolactose by thiogalactoside trandacetylase. This allolactose (in a sufficient amount), binds to the repressor protein, causing a conformational change that no longer allows the repressor to bind to the operator. As a result, the RNA polymerase can now bind and produce enzymes that break down lactose for cell use.
  - The operon is induced: it is constantly "off", but can be turned on

- Some organisms prefer glucose over lactose, adn as a result, have repressible operons for glucose. However, when glucose is absent, cAMP is not not consumed by the glucose operon, and cAMP builds up. THis, along with the presence of galactose, turns on the inducible operon for the breakdown of lactose. This occurs when there is not enough glucose present for the organism's necessary processes.
- Borrelia burgdorferi: Lyme disease
- Francisella tularensis: Tularemia

6. Gene Expression and Cell Specialization:

- Organisms must be able to turn certain genes on/off in response to external stimuli from the environment. If not, they risk wasting resources.
- DNA methylation: the addition of methyl groups (—CH3) tto DNA
  - Causes the expression of genes to stop
- Histone acetylation: the attachment of acetyl groups (-COCH3)
  - Causes the expression of genes to increase; loosens the compactness of DNA
- Methylation and acetylation can be inherited AND reversed
- Regulation of mRNA: miRNAs and siRNAs can bind to mRNA and degrade it or block translation.
- Post-transcriptional modifications can degrade protein and use amino acids later

7. Mutation:

- Deletion: chromosome fragment removed
    - Frameshift: usually a result of deletion; codons all shift one place, causing a change in the sequencing
    i. Often very severe
- Insertion: addition of nucleotides to DNA
- Mismatch repair: where enzymes remove incorrect sequencing caused by mutations
- Missense: only one amino acid affected
- Nonsense mutation: A mutation that changes an amino acid codon to one of the three stop codons, resulting in a shorter and usually nonfunctional protein.
- Nucleotide excision repair: A repair system that removes and then correctly replaces a damaged segment of DNA using the undamaged strand as a guide.
- Point mutation: gene mutation in which a single base pair in DNA has been changed
- Silent mutations: a mutation that occurs in which the expression is not changed; often a result of the redundant RNA codon sequences, and a point mutation in the 3rd nucleotide sequence of the codon
- Telomerase: enzyme responsible for the length of telomeres .
- Telomere: repeated DNA sequences at the end of the chromosome; meant to prevent the shortening of DNA during replication and the removal of important sequences

Sources

- www.khanacademy.org