Guided Notes
Unit 5: Molecular Genetics

Chapter 8: From DNA to Protein

I. Concept 8.4: Transcription

a. Central Dogma of Molecular Biology
   i. Information flows in one direction:
      1. ___________ → ___________ → ___________
   ii. How?
      1. _________________: process where DNA’s nucleotide sequence is
         converted to the form of a single-stranded RNA molecule, which will leave the nucleus and
         direct the making of proteins in the cytoplasm
         a. DNA → RNA
      2. _________________: process that converts RNA into amino acid chain
         (called a polypeptide)
         a. RNA → Amino Acid Chain (Polypeptide – AKA “Protein”)
b. Ribonucleic Acid (RNA)
   i. RNA is the link between ____________ and ________________.
   ii. RNA (ribonucleic acid): _______________________________________________________
       ______________________________________________________________________________
   iii. 3 Differences of RNA from DNA
         1. Its sugar is ribose (rather than the deoxyribose of DNA)
         2. RNA forms a single, sometimes twisted strand (not a double helix like DNA)
         3. Its nitrogenous bases are ACGU (unlike ACGT in DNA) - U stands for uracil
            a. Uracil (U): _______________________________________________________
               (U takes the place of the T of DNA - similar in structure to T and pairs with A)

   c. Transcription
      i. DNA → RNA
      ii. Two DNA strands separate at the place where transcription will start
      iii. RNA bases pair with complementary DNA bases
      iv. RNA polymerase: _______________________________________________________

      v. During transcription, RNA nucleotides base-pair one by one with DNA nucleotides on one of the
         DNA strands (called the template strand). RNA polymerase links the RNA nucleotides together.
II. **Concept 8.5: Translation**

a. **Amino Acids**
   i. **RECALL**: A polypeptide is a _________________.
   ii. Every ________________ (called a ____________) code for one ________________.

b. **The Codon**
   i. ACGU allows for ___________ codon combinations - 61 of the 64 triplets code for amino acids
   ii. **3 STOP Codons**
      1. 3 codons do not code for amino acids are "stop codons" (come at the end of each gene sequence)
   iii. **1 START Codon**
      1. The codon ___________ not only stands for methionine (Met), but also functions as a signal to "start" translation

   c. Each codon stands for a particular amino acid. (The table uses abbreviations for the amino acids, such as Ser for serine.)
d. **Translation**
   i. RNA $\rightarrow$ Amino Acid Chain (Polypeptide – AKA “Protein”)
   ii. The anticodon on tRNA recognizes a particular codon on mRNA by using base-pairing rules
   iii. An enzyme specific for each amino acid recognizes both a tRNA and its amino acid partner and links the two together
   iv. **Ribosome:** it coordinates the functioning of mRNA and tRNA; made of ribosomal RNA (rRNA); has two binding sites: one for mRNA on its small subunit and two for tRNA on its large subunit

III. **Concept 8.7: Mutations**
   a. Mutations
      i. **Mutation:** (This is a change in the nucleotide sequence of DNA and can involve anywhere from large regions of a chromosome or just a single nucleotide pair.)
      ii. Mutations may or may not affect the phenotype (physical traits) of an organism and/or its offspring.
      iii. Types of Mutations
         1. Many types of mutations can occur, especially during DNA replication.
         2. ________________________________
            a. Base substitution
            b. Frameshift mutation (insertion or deletion)
         3. ________________________________
            a. Gene duplication
            b. Gene insertion
            c. Gene deletion
            d. Gene inversion
            e. Gene translocation
            f. Nondisjunction
iv. Single Gene Mutations

1. Base substitution: ________________________________
   ________________________________ - can cause anywhere from no change (when new codon
codes for same amino acid - called a silent mutation) to drastic changes

2. Insertion or deletion: ________________________________
   ____________________________________________ (usually more disastrous than a base substitution)

   a. Because mRNA is read as a series of triplets, adding or subtracting nucleotides
      may alter the triplet groupings of the genetic message. Therefore, all the
      nucleotides that are "downstream" of the mutation will be regrouped into different
      codons. These new codons code for new amino acids. The result will be a
      different, and probably nonworking, protein.

v. Chromosomal Mutations

1. Chromosomal mutations affect many genes. These occur during the first part of meiosis in
   a process called crossing over.

2. Gene duplication: occurs when ________________________________
   ________________________________ - one chromosome will have two copies of a gene - caused
   by unequal alignment of chromosomes during crossing over (the other chromosome of the
   homologous set will be missing the gene)
3. Gene insertion: occurs when ____________________________________________________

4. Gene deletion: occurs when ____________________________________________________ (large deletions tend to have very serious effects on the body - as whole proteins may not be coded for)

5. Gene inversion: involves ______________________________________________________

6. Gene translocation: occurs when ________________________________________________

7. Nondisjunction: occurs when __________________________________________________ - causes errors in chromosome number
b. Effect of Mutations

i. Some gene mutations: 
   1. A mutation may cause a premature stop codon.
   2. A mutation may change protein shape or the active site.
   3. A mutation may change gene regulation.

ii. Some gene mutations: 
   1. A mutation may be silent.
   2. A mutation may occur in a noncoding region.
   3. A mutation may not affect protein folding or the active site.

iii. Some gene mutations: 
   1. A mutation in sex cells can be harmful or beneficial to offspring.

c. Mutagens

i. Mutations occur: 
   1. When errors are made during DNA replication.
   2. When errors are made during chromosome crossovers in meiosis (that's how mutations are passed on to offspring!).

ii. Mutagens: 

iii. Most common **physical mutagen**: high-energy radiation (like X-rays and ultraviolet (UV) light)

iv. **Chemical mutagen**: when chemicals that are similar to normal DNA bases cause incorrect base-pairing when incorporated into DNA

v. Fun Fact!: Some mutations can alter a protein in a way that may be beneficial in certain environments.

Chapter 5: Cell Growth and Division

IV. **Concept 5.5: Multicellular Life**

a. Cell Differentiation

i. Gene expression:

ii. Cell differentiation:

iii. What makes each cell different?
   1. A cell’s location in an embryo helps determine how it will differentiate.
   2. A particular cell only expresses genes that code for proteins with functions in that cell.
3. Though all the genes (DNA) are present in every type of cell, ___________________________ are actually expressed in each type of cell.

b. Stem Cells
   i. Stem cells: ____________________________________________________________ - they have the potential to differentiate into various types of cells
   
   ii. Stem cells have the ability to:
   
   1. Divide and renew themselves
   2. Remain undifferentiated in form
   3. Develop into a variety of specialized cell types

   iii. Types of Stem Cells
   
   1. Stem cells can be classified into different types.

<table>
<thead>
<tr>
<th>Type of cell</th>
<th>fertilized egg</th>
<th>embryonic stem cell</th>
<th>adult stem cell (example from blood)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can give rise to</td>
<td>all cells</td>
<td>almost any cell</td>
<td>closely related cells</td>
</tr>
<tr>
<td>Example</td>
<td>new organism</td>
<td>neurons, skin, muscle, kidney, cartilage, bone, liver, pancreas</td>
<td>red blood cells, platelets, white blood cells</td>
</tr>
</tbody>
</table>
iv. Uses of Stem Cells

1. Embryonic stem cells can be grown indefinitely by scientists in lab cultures.

   (1) Egg is fertilized by sperm cell in petri dish. (2) Egg divides, forming an inner cell mass. (3) Cells are removed and grown with nutrients. (Scientists control how the cells specialize by adding or removing certain molecules.

2. Some types of tissues, such as nervous tissue and heart muscle, do not have stem cells that exist in the adult individual. Yet, embryonic stem cells may be able to help people with disabling diseases that affect such tissues, but some people question the ethics of this technology.

Chapter 9: Frontiers of Biotechnology

I. Concept 9.1: Manipulating DNA

a. Manipulating DNA
   
   i. Scientists use various tools to manipulate DNA for their research.
   
   ii. Chapter 9 discusses technologies such as:
   
   1. Restriction enzymes
   2. Restriction maps
   3. Gel electrophoresis
   4. DNA fingerprinting
   5. Polymerase Chain Reaction (PCR)
   6. Genetic engineering (such as cloning and recombinant DNA technology)
   7. Bioinformatics

b. Restriction Enzymes
   
   i. How does a biologist remove a gene from one DNA molecule in order to better study it for their research?
   
   ii. Restriction enzymes: _____________________________________________________________
iii. Each restriction enzyme recognizes particular short nucleotide sequences (called ___________ ___________) in DNA molecules, and cuts sugar-phosphate bonds in the DNA backbone at specific points within these sequences.

iv. Different restriction enzymes cut DNA in different ways.

c. Restriction Maps

i. Restriction maps show _______________________________________________________________________.

d. Gel Electrophoresis
   
i. Gel electrophoresis: __________________________________________________________
   
ii. Each DNA sample is cut up into fragments by restriction enzymes and placed in the gel. All DNA molecules are __________________________, so they move through pores in the gel toward the ________________ pole.

iii. The shorter DNA fragments slip more easily through the pores of the gel. Therefore, __________

The DNA fragments show up as a series of bands in each "lane" of the gel.

II. Concept 9.2: Copying DNA

a. Polymerase Chain Reaction (PCR)
   
i. PCR: __________________________________________________________
   
1. (PCR can generate 100 billion identical molecules from a single strand in just a few hours!)

ii. PCR is similar to DNA replication.
b. Result
   i. Each PCR cycle ________________________________________________________
   
   ![PCR Cycle Diagram]

   ii. Using PCR to produce multiple copies of a DNA sample can:
       1. Make further analysis of the sample much easier.
       2. Enable scientists to make copies of very rare DNA (such as 5,000-year-old human remains, a 40,000-year-old woolly mammoth frozen in a glacier, or a 30-million-year-old plant fossil).
       3. Make it possible to detect viral genes in cells infected with the virus that causes AIDS.

III. **Concept 9.3: DNA Fingerprinting**
   
   a. DNA Fingerprinting
      
      i. DNA fingerprint: ________________________________________________________ on an electrophoresis gel, determined by restriction fragments of the person's DNA

   ![DNA Fingerprint Diagram]

      ii. The probability that two people share identical numbers of repeats in several locations (resulting in an identical fingerprint) is very small.
b. Uses of DNA Fingerprinting
   i. Evidence in criminal cases
   ii. Paternity tests
   iii. Immigration requests
   iv. Studying biodiversity
   v. Tracking genetically modified crops

c. Making a DNA Fingerprint
   i. Using PCR and gel electrophoresis, a DNA fingerprint can be made from cells in a single drop of blood or from a hair follicle.
      1. DNA is __________________________ from the small sample.
      2. Multiple __________________________ using PCR.
      3. __________________________ using a gel.
   ii. In most cases, the probability of two people having identical genetic markers is small—somewhere around 1 in 1 billion.

IV. Concept 9.4: Genetic Engineering
a. Cloning
   i. Clone: __________________________________________________________

   ii. Cloning occurs in nature:
      1. Bacteria (binary fission)
      2. Some plants (from roots)
      3. Some simple animals (budding, regeneration)
   iii. Mammals can be cloned through __________________________.
      1. Nucleus is removed from an egg cell.
      2. Nucleus of a cell from the animal to be cloned is implanted in the egg.
iv. Benefits
   1. Organs for transplant into humans
   2. Save endangered species

v. Concerns
   1. Low success rate
   2. Clones “imperfect” and less healthy than original animal
   3. Decreased biodiversity

b. Recombinant DNA
   i. Recombinant DNA: ____________________________________________________________

ii. Bacterial plasmids are often used to make recombinant DNA.
   1. Plasmid: ___________________________________________________________________
   2. A plasmid is separate from the much larger bacterial chromosome and is passed from one bacterium to another, resulting in gene "sharing" among bacteria. *(This is how an increasing variety of bacteria that cause human disease are becoming resistant to current antibiotics.)*

3. Biologists use plasmids to move pieces of DNA, such as genes for useful products, into bacteria. This procedure is called ____________________________.
iii. How to Create Recombinant DNA

1. A ________________________ cuts the DNA fragments.
2. A DNA fragment from another source is added.
3. The fragments stick together by base-pairing.
4. ________________________ pastes the fragments together.
5. The bacterial cell takes up the recombinant plasmid.
6. The bacterial cell divides and creates ________________________ of the plasmid.

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c. Transgenic Organisms

i. Transgenic organism: _____________________________________________________________
______________________________________________________________________________

ii. (Genome: _________________________________________________________________)

iii. Transgenic Bacteria

1. Transgenic bacteria can be used to produce human proteins.
2. Examples:
   a. Bacteria that break down certain chemicals and help to clean up toxic waste sites
   b. Bacteria engineered to mass-produce useful chemicals, from pesticides to
      therapeutic drugs
c. Bacteria produce human insulin that can be used in the treatment of some types of diabetes
d. Bacteria used in the development of effective vaccines against disease-causing microbes

iv. Transgenic Plants

1. Transgenic plants are common in agriculture.
2. How? Transgenic bacteria infect a plant, then the plant expresses the foreign gene.
   a. Many crops are now genetically modified (GM).

3. Using recombinant DNA technology, scientists are able to improve various characteristics (like delayed ripening, improved nutritional content, and resistance to spoilage or disease) of certain crop plants.

v. Transgenic Animals

1. Transgenic animals are used to study diseases and gene functions.
   a. Transgenic mice are often used to study development, disease, and gene function.
2. Genetically modifying animals is more difficult than producing GM plants.
3. Goals of genetically modifying an animal might include:
   a. To make a sheep with better-quality wool
   b. A pig with leaner meat
   c. A fish that will mature in a shorter time
   d. To make a transgenic animal that produces a large amount of an otherwise rare biological substance for medical use (like adding a gene for a desired human protein, such as a hormone, to the genome of a farm mammal)
d. GMO Concerns
   i. Genetically modified organism (GMO):

   ii. Questions that scientists have include:
      1. Are crops carrying artificially inserted genes safe?
      2. Could they be harmful to human health or to the environment?
   iii. Concern to Environment: GM crops could

   iv. Concern to Human Health: GM plants or animals could

V. Concept 9.5: Genomics and Bioinformatics
a. Genomics
   i. Genomics:
      (including the sequencing of genomes and comparisons of genomes within and across species)
   ii. Gene sequencing:

   iii. The genomes of several different organisms have been sequenced.
b. Human Genome Project
   i. 1990: advances in DNA technology enabled scientists to tackle the challenge of

   ii. 2000: rough draft of the entire sequence was completed
      1. The DNA sequences determined by the Human Genome Project are entered into a database that is available to researchers all over the world through the Internet.
      2. Scientists are still working to identify and map all human genes.
   iii. Benefits
      1. Comparing human sequences with those from other species allows for insight into human embryonic development and
      2. For, identifying genes will aid in diagnosing, treating, and possibly preventing many common ailments.