Chapter 2: Cell Biology and DNA

Objectives

After completing this chapter you should be able to:

1. describe and label the parts of the eukaryotic cell;
2. describe the types of cells found in the human body;
3. describe chromosome structure and identify human karyotypes;
4. describe the differences between mitotic and meiotic cell division;
5. understand the importance of crossing over and recombination;
6. describe DNA structure, DNA replication, transcription, and translation;
7. calculate the sequence of bases in DNA or RNA when provided with the complementary strand, and translate the codons into amino acids using the chart.

Key Words

Cell

Nucleus

Prokaryotic

Eukaryotic

Somatic cells

Gametes

Chromosomes

Chromatid

Centromere

Homologous pairs

Genes

Alleles

Karyotype

Nondisjunction

Mitosis

Zygote

Diploid

Meiosis

Haploid

Recombination (crossing over)

Double helix

Nucleotides

Complementary base pairs

Self-replication

Protein synthesis

Amino acids

Transcription

Translation

RNA

mRNA

Ribosome

Codon

tRNA

Pre-Lab Questions

1. Which of the following individuals was responsible for coining the term "cell"? **(a) Hooke**, (b) Darwin, (c) Wilkins, (d) Watson
2. Prokaryotic cells are distinguishable from eukaryotic cells because prokaryotes do *not* contain: (a) organelles, (b) a plasma membrane, (c) DNA, **(d) a nucleus**.
3. Chromosome strands are called (a) centromeres, (b) alleles, **(c) chromatids**, (d) homologues.
4. Alternate forms of a gene are called **(a) alleles**, (b) sister chromatids, (c) homologues, (d) replicated DNA.
5. Sister chromatids separate during nuclear division in (a) mitosis, (b) meiosis I, (c) meiosis II, **(d) both a and c**.
6. Who won the Nobel Prize in 1962 for identifying the structure of DNA? (a) Hooke, (b) Meischer, (c) Watson and Franklin, **(d) Watson, Crick, and Franklin**
7. Which of the following is a possible base pairing in DNA? (a) adenine-cytosine, **(b) adenine-thymine**, (c) cytosine-thymine, (d) thymine-guanine
8. Transcription in DNA (a) results in the formation of an identical DNA strand, **(b) results in the formation of mRNA**, (c) happens in the nucleus, (d) requires the assistance of tRNA anticodons.
9. True or **False**: DNA replication occurs in the ribosome.
10. **True** or False: Crossing over is an important source of variability.

In-Class Exercises

Exercise 1

Can you think of any reason why the gametes have only 23 chromosomes, one of each pair?

When they combine during fertilization, the zygote will have the correct number of chromosomes, one of each pair from mom and the other of each pair from dad.

Chimpanzees have 48 chromosomes in their somatic cells. How many chromosomes do you think are found in their sex cells? *24*

Exercise 2

Exercise requires karyotype and answers will vary

Exercise 3

Compare and contrast mitosis and meiosis in the human with the following matching questions:

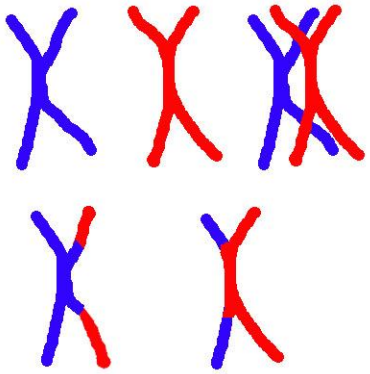
a	1. happens in the body cells	a. mitosis
b	2. produces 4 daughter cells	
c	3. begins with 46 chromosomes	b. meiosis
a	4. produces 2 daughter cells	
a	5. one nuclear division	c. both mitosis and meiosis
c	6. one chromosome replication	
b	7. happens in the testes and ovaries	
b	8. daughter cells have 23 chromosomes each	
b	9. two nuclear divisions	
a	10. daughter cells are diploid	

Exercise 4

Draw a homologous pair of chromosomes. Use one color (e.g. pink) for one member of the pair and use a second color (e.g. blue) for the second member of the pair.

Next, draw the two chromosomes crossing over so that the two colors are touching. Third, draw the two chromosomes after the crossing over is completed and they have shuffled their gene pairs, exchanging genes (colors) between them. Have at least one exchange. Compare your drawing to others in the class and see the amount of variation that might be possible.

Answers will vary but may look like the following:



Exercise 5

Practice DNA base pairing:

Consider the following DNA strand:	A T C C T A G G T C A G
Identify the complementary bases:	*T A G G A T C C A G T C*

Now, practice DNA replication. Consider the following double stranded DNA molecule. Notice that the DNA bases are paired accordingly. Separate the strands and replicate them, identifying which strands are original and which are the new complementary strands.

New strand: *A T G C C G T T G A C T C G A*

Top strand: T A C G G C A A C T G A G C T

Bottom strand: A T G C C G T T G A C T C G A

New strand: *T A C G G C A A C T G A G C T*

Exercise 6

The following chart lists all possible mRNA codons and the 20 amino acids they code for. Note that there is some redundancy in the code. Also, note that some codons code for start or stop, which tells the cell where to start or stop making the protein. Using this information, find the amino acid each codon calls for below.

UCA	*Serine*	GUA	*Valine*
UGG	*Tryptophan*	AGA	*Arginine*
CUC	*Leucine*	GCC	*Alanine*
CAU	*Histidine*	AUG	*Start (Methionine)*

Exercise 7

The following is a template strand of DNA:

A C G G T T C A T G C A

What is the complimentary mRNA strand?

U G C C A A G U A C G U

What are the complimentary tRNA anticodons?

ACG; GUU; CAU; GCA

Using the chart from the previous exercise, what is the sequence of amino acids for this peptide chain? Be sure to use the mRNA codons when reading the chart!

Cysteine; Glutamine; Valine; Arginine

Post-Lab Questions

1. Describe the difference between the autosomes and the sex chromosomes.

   Autosomes are always homologus pairs and contain information pertaining to body structure and function; they comprise pairs 1-22 in humans. The sex chromosomes (pair 23) are homologus in females but not in males, since the X and Y chromosome are different lengths and the Y chromosome carries information only pertaining to the biological sex of the individual.

2. How many chromosomes were there in your karyotype set? Was this the normal number for humans?

   This depends upon the student's karyotype. 46 is the normal number.

3. Referring to your lecture textbook, or the internet, discuss the clinical symptoms associated with any anomaly you identified in your karyotype.

   Student activity, answers will vary.

4. How do you determine the sex of an individual when examining their karyotype?

   By looking at the sex chromosomes – if there are 2 identical chromosomes, the individual is XX and female. If one of the chromosomes is small and the other is large, the individual is XY and male.

5. How are the different types of chromosomes identified for a karyotype?

   Based on size, length of arms and position of the centromere.

6. If the chromosome number for an organism is 22 before mitosis, what is the chromosome number of each daughter cell after mitosis has taken place?

   22

7. Why is the DNA replicated prior to mitosis?

   So that each daughter cell has the complete complement of chromosomes.

8. What do you think might happen if a cell underwent mitosis but not cytokinesis?

   The cell without the cytoplasm and associated organelles would not survive (this is common in females, one gamete gets all cellular contents, the ovum, while the other three get little/none and are called polar bodies, which resorb).

9. If a cell in an organism had 16 chromosomes before meiosis, how many chromosomes would exist in each nucleus after meiosis? What is the diploid number? What is the haploid number?

   8 after meiosis, 16 is diploid, 8 is haploid.

10. From a genetic standpoint, what is the significance of fertilization?

    It is when the egg and sperm meet, allowing the 23 chromosomes from the mother to unite with the 23 chromosomes from the father (in humans) creating a zygote.

11. Describe the differences between haploid and diploid cells. Where are they found?

    Diploid cells have the full complement of chromosomes with all the homologous pairs. Haploid cells have only half of the complement of chromosomes, with only one of each chromosome from each homologous pair.

12. Discuss the differences you observed when comparing your crossing over diagram to others in the class. How many different combinations did you see?

    Student activity – answers will vary because each person's diagram will be at least slightly different.

13. What does it mean when we say DNA replication is semiconservative?

    Each parental strand remains intact, while a new complementary strand is formed.

14. Describe the differences in DNA and RNA structure.

    DNA is double stranded while RNA is single stranded; DNA has a deoxyribose sugar, RNA has ribose sugar; DNA has thymine, RNA does not, but has Uracil.

15. To transcribe means "make a copy of". Is an exact copy of DNA made during the process of transcription? Why or why not? *No, because RNA does not have thymine, so it replaces it with Uracil. Also, because of the law of complementary bases, the RNA strand is actually a "mirror image" of the DNA strand that is being copied.*

16. Where does transcription happen? What about translation?

    Transcription happens in the nucleus, translation occurs in the ribosome.

17. What amino acid would be produced if transcription took place from the DNA sequence CAT?

    (mRNA would be GUA) amino acid is Valine.

    If a genetic mistake took place during replication and the new DNA strand has the sequence CAG, what amino acid would this result in? (mRNA is GUC), amino acid is *Valine.*

    What if the genetic mistake resulted in a DNA strand with the sequence GAT? (mRNA is CUA), amino acid is *Leucine.*

Explain these results. *Because there is some redundancy in the codons versus amino acids some genetic mistakes will not result in a change of amino acids, while other mistakes will.*