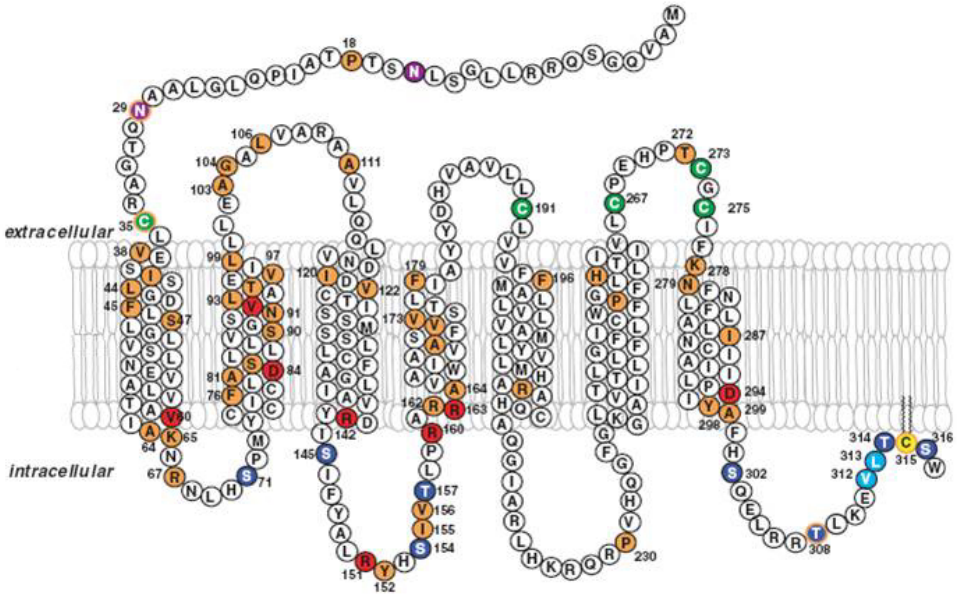
Review Activity Module 2: Cells and Division

Laroche:



During module 4 on evolution, we will spend several classes examining the evolutionary significance of fur colour in a certain group of mice from the Sonoran desert in the South-Western United States. To prepare for this module, in the review activities for the first 3 modules we will be examining the molecular, cellular, and genetic basis for mouse coat colour.

In the review activity for unit 1, you examined the MC1R molecule displayed above. MC1R is a transmembrane receptor protein involved in a typical cell communication pathway. What organelles in the cell could conceivably play a role in producing the MC1R molecule and directing it to the appropriate location within the membrane of the cell? For each organelle you list, describe what it would actually do.

Nucleus: House the DNA which has the instructions for producing MC1R, produce the mRNA working copy of this gene.

Ribosomes: Translate the mRNA of MC1R into the actual protein.

RER: Site for protein synthesis using ribosomes; modify and process the protein to help it towards taking its final shape.

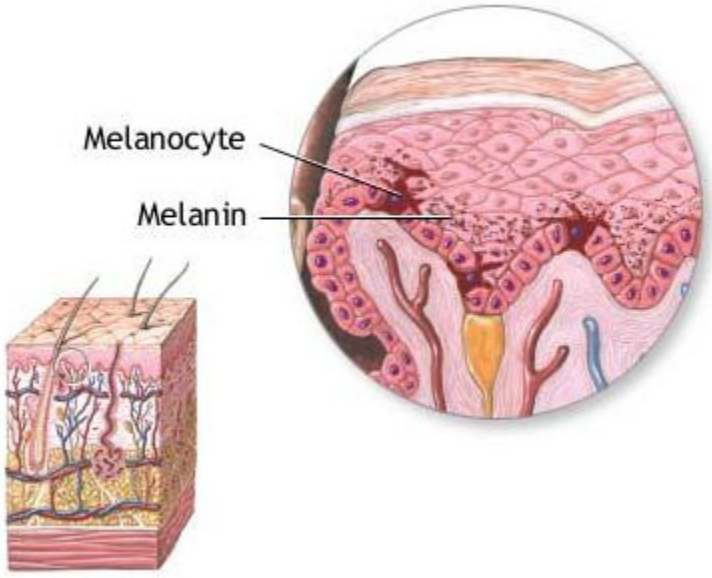
Golgi: Modify and process the protein further, package and embed it in a vesicle membrane for shipping.

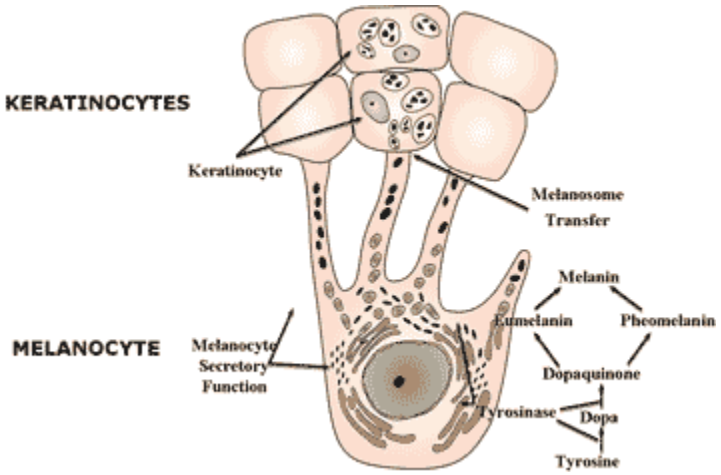
Vesicle: Move the molecule to the plasma membrane, fuse with the membrane, inserting MC1R into its final location.

Cytoskeleton to act as tracks for vesicles.

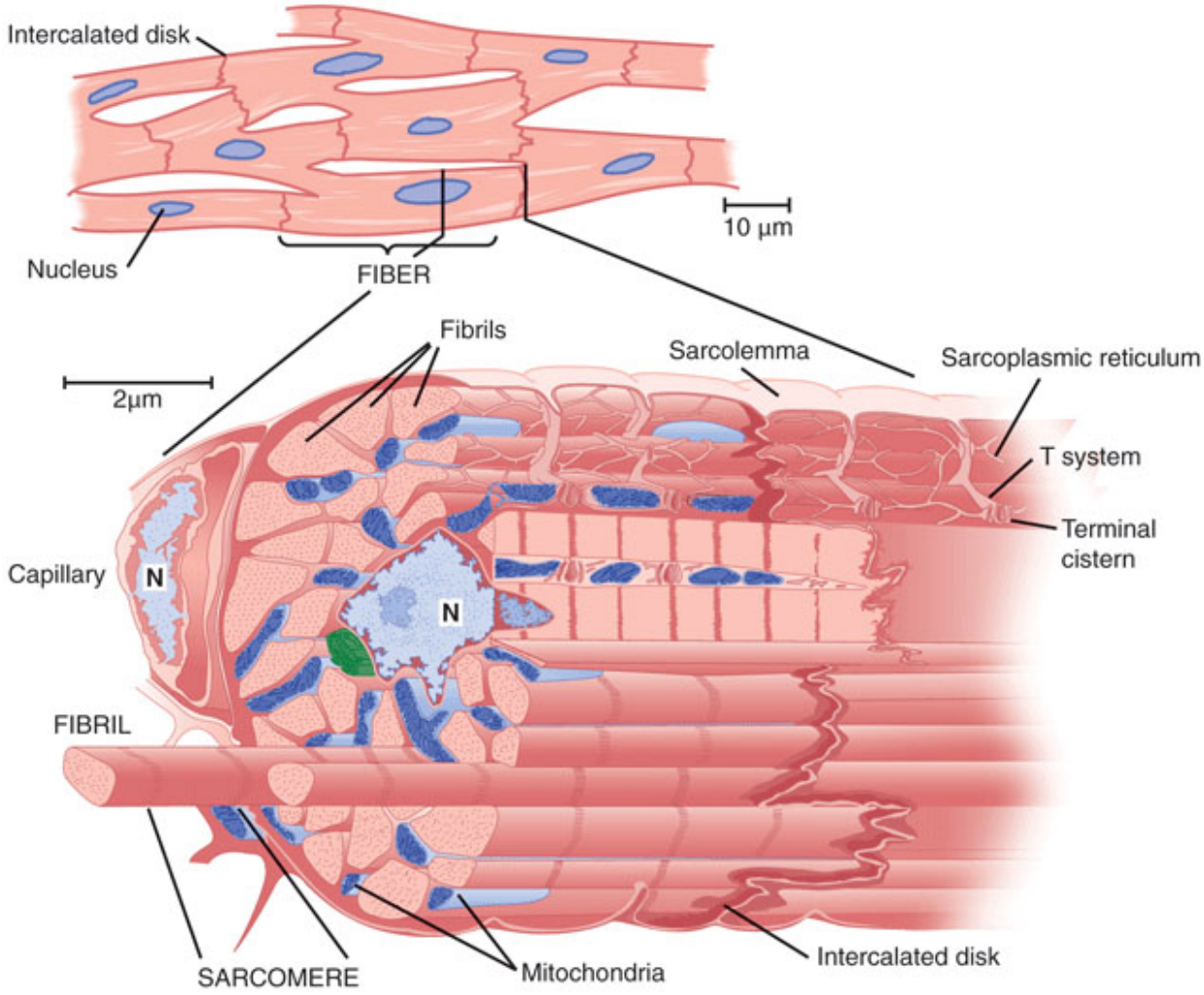
Use information on three different types of cells from the following paragraphs and images in order to answer the subsequent questions.

MC1R is found in the cell membrane of melanocytes, which are cells located in the bottom layer of the skin's epidermis, as well as several other locations in the body. The primary function of melanocytes is to produce the pigment melanin (a molecule based on the amino acid tyrosine, but which is **NOT** a protein), which they package in vesicles called melanosomes. These vesicles are then exported out of the melanocyte and into surrounding cells called keratinocytes, which eventually move from the lower part of the skin to the surface, resulting in pigment deposition near the skin's surface.

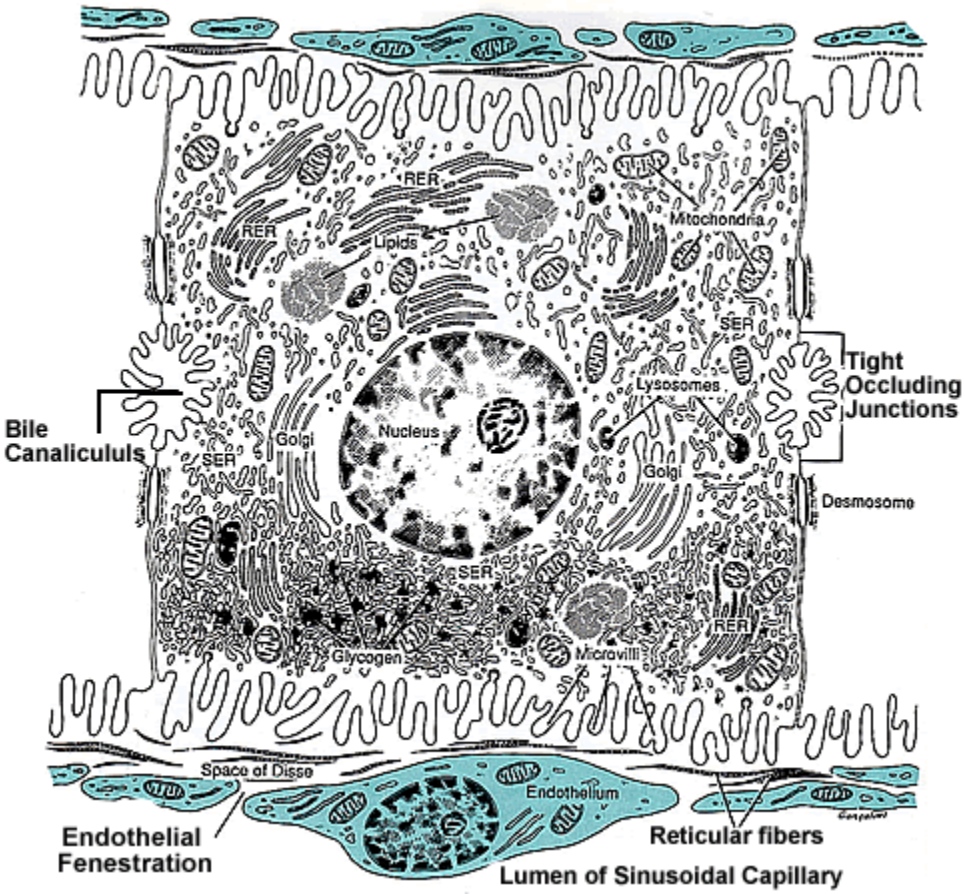




Below is an image of a cardiac myocyte, which is a heart muscle cell. These cells exhibit striations formed by alternating segments of thick and thin protein filaments, and their primary function is to move these filaments against each other to contract and relax (or expand) the shape of the cell.



Below is an image of a hepatocyte, which is a liver cell. Among many other things, liver cells function in the detoxification of waste products, drugs, and hormones.



Based on the functions of the three types of cells described in the preceding paragraphs (i.e., only consider the drug detox function for liver, and not the many other functions of liver cells), compare and contrast melanocytes, myocytes, and hepatocytes in terms of their organelle constituents. What types of organelles are melanocytes likely to have more of, and why? What about myocytes and hepatocytes?

The primary function of melanocytes is to produce melanin and ship it out of the cell. Melanin isn't a protein, so its synthesis does not take place in the RER. Instead, it is produced in specialized vesicles called melanosomes. However, like many vesicles in the cell (and almost all that are destined for export), these melanosomes are produced in the Gogli. Thus, one would expect melanocytes to have a higher than average amount of Golgi bodies, due to their function of exporting molecules from the cell.

Myocytes are all about movement, and movement takes energy. The energy currency for cells is a molecule called ATP, and ATP is produced from the oxidation of C-H bonds (from carbs and lipids) in mitochondria. Thus, one would expect myocytes to have more, and maybe many more mitochondria than average cells. Muscles are also very high in protein, due to the extensive networks of protein filaments. Therefore, muscle cells should contain a higher amount of RER for the production of all of these protein filaments.

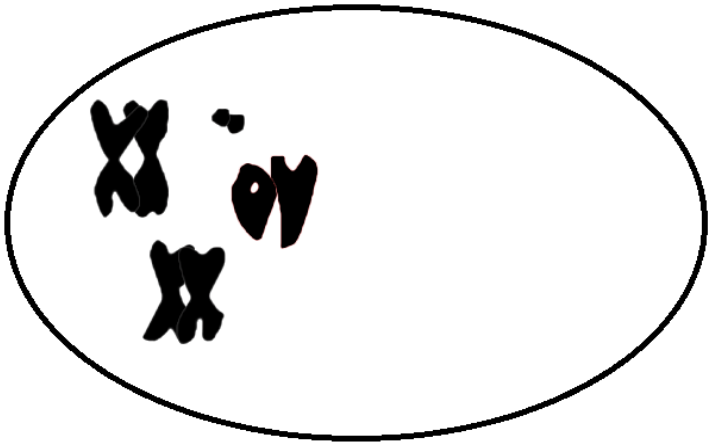
As mentioned, hepatocytes have MANY functions, and they have lots of different organelles accomplishing these. However, for the stated purpose of detoxification of waste products, hormones, and drugs, hepatocytes require a large amount of SER, as this is the organelle which contains the enzymes necessary to accomplish these tasks. Thus, hepatocytes tend to be very high in SER.

A single cell in G1 from a specific culture of rapidly dividing cancer cells was isolated and fused with a cell in the early stages of G1 that was obtained from a normal culture of slowly dividing cells. No change was observed in the normal cell, but the nucleus from the cancer cell failed to initiate the S phase as predicted, and instead remained in G1. When subjected to further analysis, it was determined that cells from the normal culture contain a protein molecule previously identified as pRb, but that the cancer cells lack this molecule. Using the internet as a resource, and employing basic Biology language encountered in this course, describe what pRb is, what it does, and how this particular molecule could be responsible for the results described above.

pRb is shorthand for a molecule known as the retinoblastoma protein. This protein belongs to a class of molecules known as tumour suppressors, because, no surprise, they prevent tumours from forming. They do this by accomplishing the everyday function of inhibiting a cell from progressing through the cell cycle. Specifically, they prevent cells from progressing from G1 into the S phase. They do this by binding to and inhibiting the function of other protein molecules which whose job it is to direct the cell into the S phase. Therefore, when certain signal molecules bind to and inhibit the function of pRb, the pRb target molecules are freed up to do their job, and the cell cycle progresses.

If, for whatever reason, pRb is not produced, is produced but is not folded properly, or is continuously bound to its own inhibitor molecules, it will not serve its function, which means it does not ‘put the brakes’ on the cell cycle, and the cell will continuously divide. The result would be a tumour, and cancer.

Using the internet, find *n* for *Drosophila melanogaster* and identify whether the species is haploid or diploid. Then, draw a primary spermatocyte cell for this species that is in late prophase I of meiosis I.



These are images of *Drosophila*'s actual chromosomes. The size and shape of the chromosomes don't actually matter for this answer. As long as you have a diploid cell with *n*=4, and homologous chromosomes paired up in tetrads, you're all good.

Make a rough sketch (i.e., just focus on the chromosomes) of all possible genetic gametes that could be produced by a *Drosophila* spermatocyte cell you just drew.

There are 16 answers for this, with every possible mix and match of the chromosomes above (within the constraints that each cell has 1 and only 1 of each of the homologs from above).

Which property of meiosis accounts for the production of the different potential gametes you just drew?

Independent assortment. There are four different tetrads made of homologous chromosomes, and each of these has two possible orientations on the metaphase plate. Thus, there are two orientations to the power of 4 different tetrads (or 2^4) possible different gamete combinations that could be produced.

Use the internet to research and describe the following human disorders. For each, be sure to identify the process which leads to the disorder.

Edward's Syndrome:

Trisomy 18, where an organism ends up with 3 of chromosome 18 due to a nondisjunction event during the meiotic production of gametes in one of their parents.

Symptoms:

http://en.wikipedia.org/wiki/Edwards_syndrome#Signs_and_symptoms

Klinefelter's Syndrome:

XXY, where an organism ends up with 2 of chromosome X as well as 1 Y. This occurs due to a nondisjunction event during the meiotic production of gametes in one of their parents (mom has an egg with 2 Xs, fertilized by a sperm with Y; Mom has an egg with X, fertilized by a sperm with XY).

Symptoms:

http://en.wikipedia.org/wiki/Klinefelter_syndrome#Signs_and_symptoms

Turner's Syndrome:

Monosomy X, where an organism ends up with only one sex chromosome (X). This occurs due to a nondisjunction event during the meiotic production of gametes in one of the parents (mom produces an egg with no X (both went into a polar body), fertilized by a sperm with X; mom produces an egg with X, fertilized by a sperm with no sex chromosome (both X and Y went into another sperm).

Symptoms:

http://en.wikipedia.org/wiki/Turner_syndrome#Signs_and_symptoms

Awad:

1. A group of cells is assayed for DNA content immediately following cytokinesis of the M phase and is found to have an average of 5 picograms (pg) of DNA per nucleus. Those cells would have _____ pg at the end of the S phase and _____ pg at the end of G1.

Immediately following cytokinesis a cell is in G1, and so 5pg of DNA is representative of the standard amount of DNA found in a cell from this species. DNA duplicates during the S phase, so you would expect 10 pg of DNA then; DNA content doesn't change during G1, so there should still be 5 pg at the end of this stage.

2. You isolate DNA from four samples of cells belonging to the same type of tissue in different phases of the cell cycle. You determine the DNA content for each type of cells. The results are depicted in the table below. Refer to the table to answer the following questions.

Cell sample	DNA content (pg/cell/nucleus ± sd)
I	**2.0 ± 0.4**
II	**4.1 ± 1.1**
III	**1.0 0.2**
IV	**3.4 ± 1.0**

a- True or false: this tissue is undergoing meiosis. Explain.

True. Cell I has 2pg, cell II has 4pg, and cell III has 1pg. This is representative of a diploid cell with 2pg doubling its DNA during the S phase, and the producing haploid cells with half the original amount of DNA through the process of meiosis. In mitosis you would only see a doubling of DNA amount, not a halving.

b- Which cell sample represents cells in S phase?

Most likely IV. Based on the answer above, with 2 being the standard diploid amount, 4 being after the S phase, and 1 being the haploid amount of DNA, it would stand to reason that, at some point, you would have 3.4pg of DNA during the S phase as the DNA is doubling.

c- From the start of the S phase to the end of the M phase, cells go from what cell sample number to what number?

IV, II, I, III ; The key here is that sample I is a cell during meiosis II, which would have the same amount of DNA as a normal G1 cell.

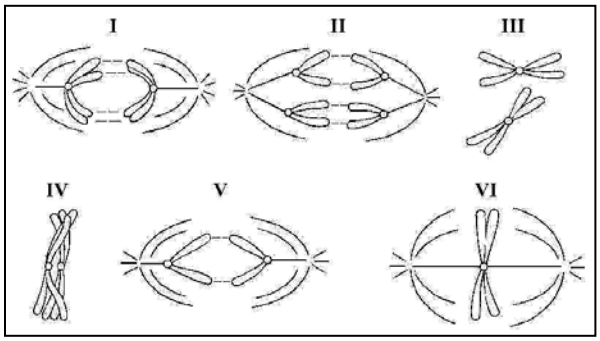
3. The following data were obtained from a study of the length of time (minutes) spent in each phase of the cell cycle by three different types of cells (designated A, B, and C) from one particular eukaryotic organism. What is the best conclusion concerning the difference between the S phases for A and B cell types?

Minutes Spent in Cell Cycle Phases

Cell type	G1	S	G2	M
A	60	0	0	0
B	20	32	16	18
C	20	50	17	26

Cell type A is likely in the G0 phase, which means it is essentially outside of the cell cycle. This is why cell type A spends no time in the S phase, while cell type B does.

4. The diagram below represents a cell with a single pair of homologous chromosomes as they might appear during various stages of either mitosis or meiosis. Which phase is represented in figure IV?



IV is prophase 1 of meiosis 1. You can tell because this is a tetrad, formed by homologous pairs (each duplicated and consisting of two sister chromatids) joining together. You can even see the synapsis and crossing over occurring.

5. When a water molecule moves from the soil into the vacuole of a cell on the surface of a root, it must pass through several cellular structures. In which order would these structures be encountered by the water molecule as it diffuses from the soil and into the cell?

Cell wall, cell membrane, vacuole membrane

6. Consider the following 4 types of cells: muscle cell, nerve cell, tracheal epithelial cell (part of the ciliated inner lining of the trachea), and enzyme-secreting cell.

a- Which cell(s) would you expect to have a well-developed endomembrane system? Justify your answer.

Enzyme-secreting cell. Enzymes are proteins, and those destined for secretion are made on the RER by ribosomes, processed there and sent to the Golgi, where they are packaged up and exported from the cell. These are all endomembrane components, and a cell whose function is to export enzymes would need lots of them.

b- Which cell(s) would you expect to have the highest surface area-to-volume ratio? Justify your answer.

The epithelial cell and the nerve cell. Epithelial cells in general tend to have a high SA/V ratio because they are often thin and stacked, but the tracheal epithelium is a special case because it is highly ciliated. These thousands of cilia dramatically increase the surface area of the cell without contributing much more volume, and so they really raise the SA/V ratio. Neurons, or nerve cells, conduct their impulses based on the diffusion in and out of the cell of particular ions. As a result, they need to have a high surface area and very little volume. Neurons consist of one main cell body, but also have VERY long and thin extensions which reach out to other neurons and conduct the impulses. These long and thin extensions have a high SA/V ratio

c- Which cell(s) would you expect to be rich in mitochondria? Justify your answer.

All of the cells would likely have a lot of mitochondria, as they all use large amounts of ATP. In the muscle this is to constantly move muscle fibers against each other for the sake of contracting; in the neuron this is to pump ions across the plasma membrane to create the electrochemical gradients which power nerve impulses; in the ciliated epithelium this is to move the cilia; and in the enzyme secreting cell it is to build and ship the proteins (likely an energy requiring process). Either way, all the cells need lots of ATP, and so have lots of mitochondria to produce this.

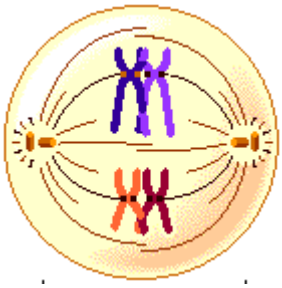
Felkai:

Define and describe the endosymbiosis theory.

The endosymbiotic theory states that several key organelles of eukaryotes originated as symbioses between separate single-celled organisms. According to this theory, mitochondria and plastids (e.g. chloroplasts), and possibly other organelles, represent formerly free-living bacteria that were taken inside another cell as an endosymbiont, around 1.5 billion years ago.

What is the cell cycle?

The cell cycle is the series of events that take place in a cell leading to its division and duplication (replication) that produces two daughter cells. The cell cycle can be divided in three periods: interphase—during which the cell grows, accumulating nutrients needed for mitosis preparing it for cell division and duplicating its DNA—and the mitotic (M) phase, during which the cell splits itself into two distinct cells, often called "daughter cells" and the final phase, cytokinesis, where the new cell is completely divided.



What stage of cell division is represented by this image? Describe what is happening.

The image displays metaphase I of meiosis I. You can tell because homologous chromosomes are paired up with each other, and lined up together in the middle of the cell on the metaphase plate. If this were mitosis, the homologous chromosomes would be lined up one on top of the other. Here, homologs have paired up, have lined up along the middle of the cell, and are preparing to separate to opposite poles of the cell.

The image above displays the karyotype of *Canis familiaris*; man's best friend. Are dogs haploid or diploid? What is *n* equal to in this species? How many chromosomes are visible in the karyotype? How many chromatids?

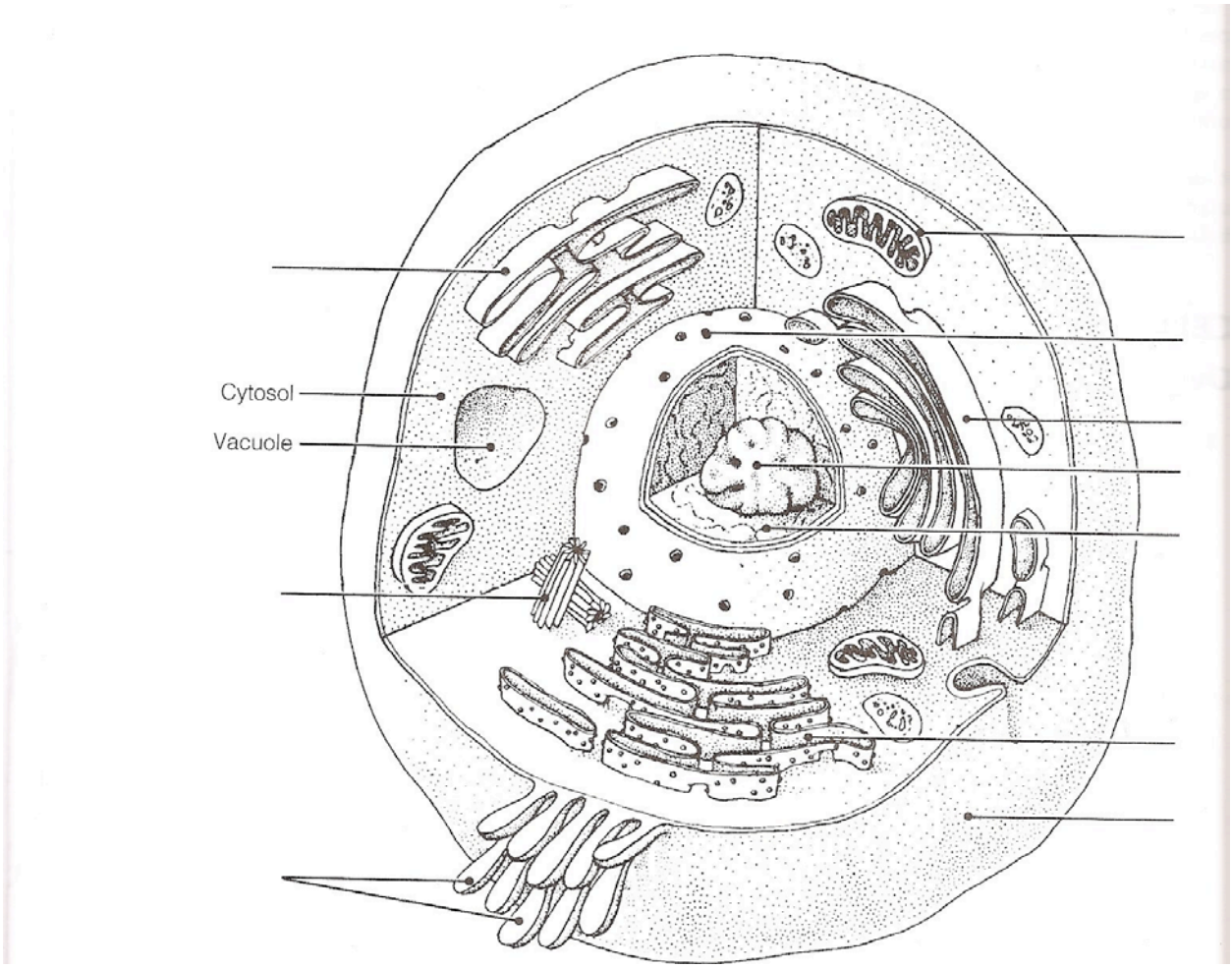
Each number identifies a pair of homologous chromosomes, and so dogs, like most animals, are diploid. There are 38 pairs, plus the X and Y sex chromosomes, which makes 39 pairs in total. In other words, *n* is equal to 39, and dogs are 2*n* (i.e., diploid), meaning there are 78 chromosomes. Count 'em. That's how many chromosomes are visible. However, karyotypes are necessarily taken during the process of division, because chromosomes need to be condensed in order to be visible. Thus, each of these chromosomes actually consists of 2 sister chromatids (having gone through the S phase and all), and so there are 156 chromatids visible in this image.

Chuck is a pre-school child who never wants to engage in active play with other children. When prompted to do so by his daycare teachers, he is typically slow, out of breath, and ultimately fatigues very easily. When his parents brought him to see a doctor, she quickly identified that he displayed a form of exercise intolerance. This is often a symptom of cardiorespiratory disorders (problems with the circular or respiratory systems, or both), and so Chuck was subjected to an entire battery of tests examining his heart, his lungs, and many other parts of his body. Unfortunately (or fortunately), all of these tests returned negative, indicating that Chuck was normal. Based on these results, what might you suggest to the doctor as a next step in her tests to identify the source of Chuck's exercise intolerance? Explain.

Chuck's problems seem to stem from a lack of energy. The mitochondria is the energy powerhouse of the cell, metabolizing sugar and fat molecules and producing ATP, which is the energy currency of the cell. If Chuck has a problem with his mitochondria, he would not produce enough ATP, and would have problems engaging in high-energy activities. Thus, the doctor should order tests to check the functioning of Chuck's mitochondria.

Sergeant:
Anatomy of a generalized cell

Using the terms given below, correctly label the parts of this cell.



- ◯ Plasma membrane
- ◯ Centriole(s)
- ◯ Chromatin thread(s)
- ◯ Golgi apparatus
- ◯ Microvilli
- ◯ Mitochondrion
- ◯ Nuclear membrane
- ◯ Nucleolus
- ◯ Rough endoplasmic reticulum (ER)
- ◯ Smooth endoplasmic reticulum (ER)

5. Relative to cellular organelles, circle the term or phrase that does not belong in each of the following groupings.

1. Peroxisomes Enzymatic breakdown Centrioles Lysosomes
2. Microtubules Intermediate filaments Cytoskeleton Cilia
3. Ribosomes Smooth ER Rough ER Protein synthesis
4. Mitochondrion Cristae ATP production Vitamin A storage
5. Centrioles Mitochondria Cilia Flagella
6. ER Nuclear pores Ribosomes Transport vesicles Golgi apparatus
7. Nucleus DNA Lysosomes Chromatin Nucleolus

6. Name the cytoskeletal element (microtubules, microfilaments, or intermediate filaments) described by each of the following phrases.

_____ 1. Give the cell its shape

_____ 2. Resist tension placed on a cell

_____ 3. Radiate from the cell center

_____ 4. Involved in moving intracellular structures

_____ 5. Are the most stable

_____ 6. Have the thickest diameter

7. Different organelles are abundant in different cell types. Match the cell types with their abundant organelles by selecting a letter from the key choices.

Key Choices

A. Mitochondria C. Rough ER E. Microfilaments G. Intermediate filaments

B. Smooth ER D. Peroxisomes F. Lysosomes H. Golgi apparatus

_____ 1. Cell lining the small intestine (assembles fats)

_____ 2. White blood cell; a phagocyte

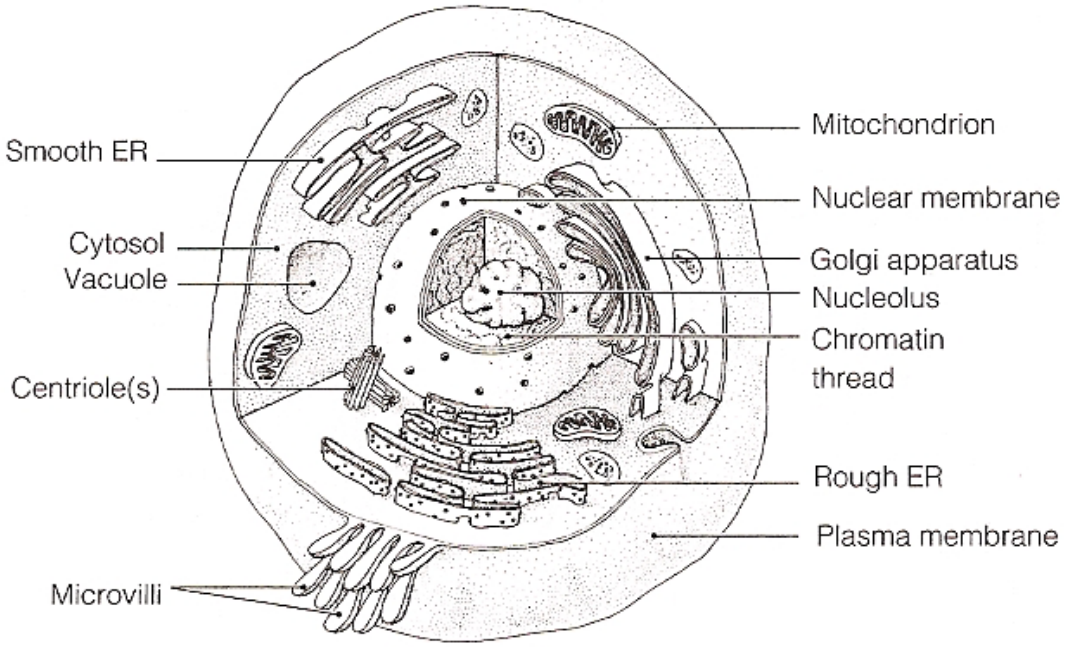
_____ 3. Liver cell that detoxifies carcinogens

_____ 4. Muscle cell (contractile cell)

_____ 5. Mucus–secreting cell (secretes a protein product)

_____ 6. Cell at external skin surface (withstands friction and tension)

_____ 7. Kidney tubule cell (makes and uses large amounts of ATP)



2.
1. Centrioles
2. Cilia
3. Smooth ER
4. Vitamin A Storage
5. Mitochondria
6. Ribosomes
7. Lysosomes

3.
1. Microtubules
2. Intermediate filaments
3. Microtubules
4. Microfilaments
5. Intermediate filaments
6. Microtubules

4.
1. B (smooth ER)
2. F (lysosomes)
3. D (peroxisomes)
4. E (microfilaments)
5. C, H (rough ER, Golgi apparatus)
6. G (intermediate filaments)
7. A (mitochondria)

PROKARYOTIC vs. EUKARYOTIC CELLS

CHARACTERISTIC	PROKARYOTIC	EUKARYOTIC
Size	smaller (0.2 - 2 mm diameter)	larger (10 - 100 mm diameter)
Plasma Membrane	yes - phospholipid bilayer	yes - phospholipid bilayer (includes carbohydrates and sterols)
Cell Wall	yes (contains peptidoglycan)	yes (EXCEPT in animal cells) (plants, fungi, some protists)
Nucleus	no (only a nucleoid)	yes (with nuclear membrane and nucleolus)
Chromosome (DNA) Arrangement	one - circular (no histone proteins)	many - linear (associated with histone proteins)
Ribosomes	yes (size = 70S)	yes (size = 80S)
Membrane-enclosed Organelles (plus names)	none	many (endoplasmic reticulum, Golgi apparatus, lysosomes, mitochondria, chloroplasts [plants only])
Cytoskeleton	no	yes
Flagella	sometimes (simple)	sometimes (complex)
Glycocalyx	sometimes (capsule or slime layer)	sometimes (some types of cells)
Phagocytosis	no	some types of cells
Cell Division	binary fission	mitosis
Sexual Reproduction	no (only plasmid transfer)	yes (meiosis)

Cells

1. Compare and contrast prokaryotic and eukaryotic cells.
Answer: Prokaryotic cells are small in size, have no membrane-enclosed organelles, are found only in domains Archaea and Bacteria, and have DNA in a nucleoid; Eukaryotic cells are 10 or more times greater in size, have membrane-enclosed organelles, are found in all domains other than Archaea and Bacteria, and have DNA in a nucleus.

2. Explain the significance of organelles. What are the costs and benefits of having large compartmentalized cells?
Answer: Organelles allow different metabolic environments to exist in the same cell. This partitioning of jobs allows for greater specialization but comes at an energy cost. Eukaryotic cells are more energy expensive.

3. What is the primary function of a cell membrane? What characteristics of membranes allow them to contribute to metabolic activity?
Answer: A cell membrane exists to form an inside and an outside of a cell. The presence of an inside and an outside allows for the establishment of different environments. In addition, membranes hold integral proteins with a variety of chemical properties and activities. This allows for the enzymatic activity associated with membranes. Stacks of membranes, such as those in mitochondria and chloroplasts, increase the amount of chemical activity in an area.

4. The organelles that contain their own DNA are all enclosed in double membranes. Relate this observation to the endosymbiotic theory.
Answer: See the textbook for a description of the origin of double membranes from endosymbiosis.

5. There are structural similarities between mitochondria and chloroplasts. If we can assume that form follows function, what would be the explanation for the similarities between these two organelles?
Answer: Both mitochondria and chloroplasts are involved in energy-transformation activities that require many enzymes. The stacking or folding of membranes provides enzymatic activity centers for these reactions.

Chapter 6: Cell Membranes

1. Cells have the ability to take in large molecules by endocytosis and secrete them to the environment by exocytosis. Describe each process and explain why both are important for the cell.

Answer: Cells take up large particles, foreign cells, and food sources by endocytosis, in which the plasma membrane of the cell surrounds the particle to form an endocytotic vesicle. Cells secrete substances such as undigested material, digestive enzymes, neurotransmitters, and material for plant wall construction by exocytosis. During exocytosis, the membrane of a secretory vesicle fuses with the plasma membrane and the contents are released to the outside of the cell.

2. A marathon runner has just arrived in the emergency room with severe dehydration, and the physician must decide which type of solution to pump into his veins: pure water, 0.9 percent saline, or 1.5 percent saline. In order to be certain, blood samples are treated with each solution and observed under a microscope. Describe what is likely to happen to the blood cells when exposed to each solution. (Hint: Blood cells are approximately 0.9 percent saline.) Which solution should the physician choose for rehydrating the runner?

Answer: In pure water, the blood cells will take on water through osmosis, swell, and eventually rupture. In 0.9 percent saline, the cells should neither gain nor lose a significant amount of water. In a 1.5 percent saline solution, the cells should lose water and shrivel. In order to rehydrate the runner, a solution isotonic to the patient's blood cells, 0.9 percent, should be infused into his bloodstream. A hypotonic solution would end up rupturing the patient's cells.

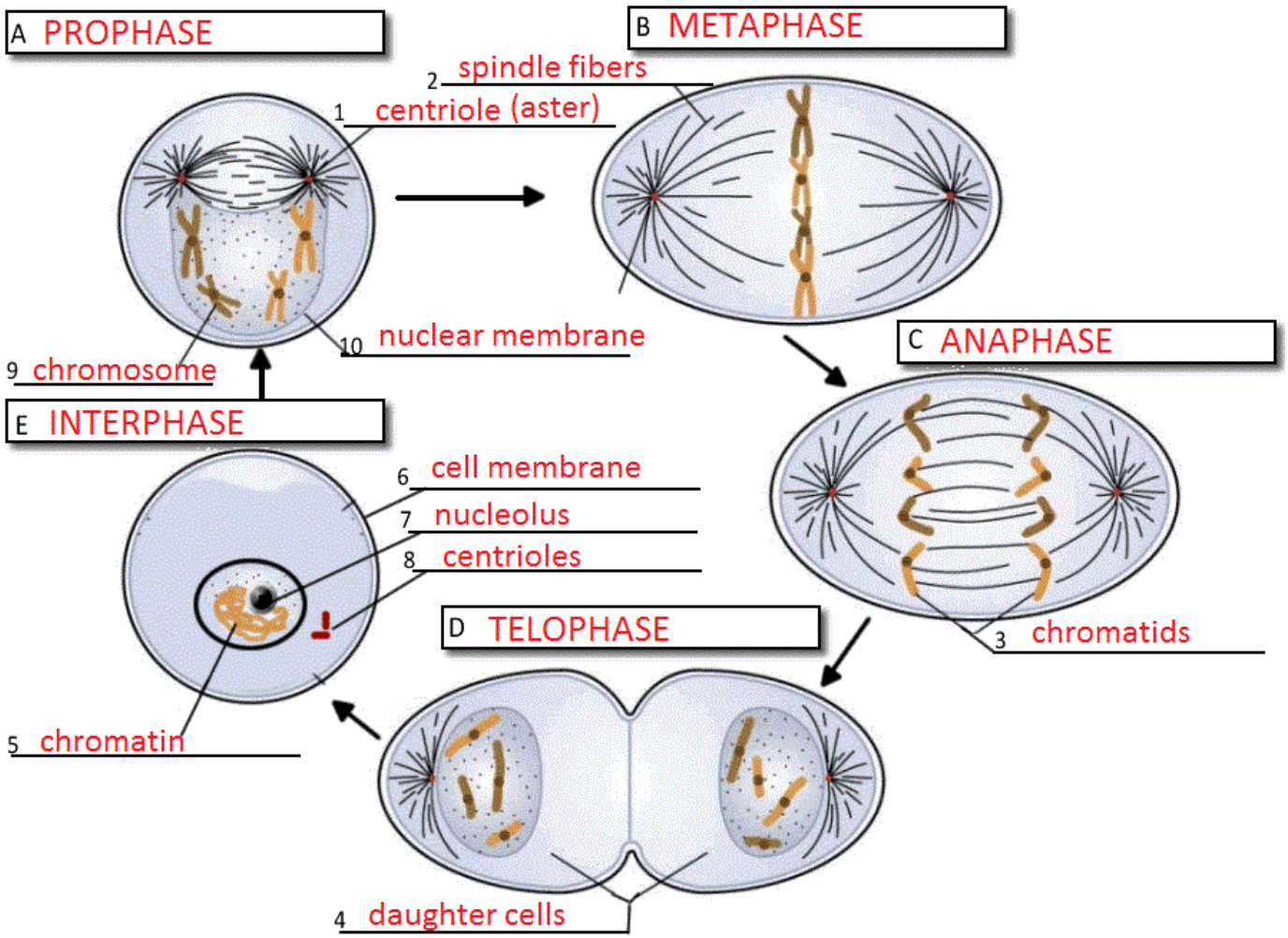
3. Compare and contrast active and passive transport.

Answer: The main difference between active and passive transport is that active transport goes against a concentration gradient and requires energy, whereas passive transport diffuses passively and does not require energy.

4. Barrier formation is only one function of the cell membrane. Describe some other functions of the membrane and discuss how the membrane is suited for those functions.

Answer: Membranes function in processing energy transformation and in the organization of chemical reactions. Integral and peripheral proteins contribute to these functions. The membrane serves as a holding site for the catalytic enzymes associated with these processes.

CELL CYCLE .....KEY | Original File: Cell Cycle Label Me



11. What moves the chromatids during mitosis? _____spindle_____
12. What anchors the spindle? _____centrioles_____
13. What are the four phases of mitosis? __prophase, metaphase, anaphase, telophase_____
14. How many daughter cells are created from mitosis and cytokinesis? _____two_____
15. During what phase does cytokinesis begin? _____telophase_____
16. If a human cell has 46 chromosomes, how many chromosomes will be in each daughter cell? __46_____
17. If a dog cell has 72 chromosomes, how many daughter cells will be created during a single cell cycle? __2____
.....Each of these daughter cells will have how many chromosomes? ___72_____
18. The nuclear membrane dissolves during what phase? _____prophase_____
19. In the cell pictured above, how many chromosomes are present during prophase? _____4_____
20. What structure holds the individual chromatids together? _____centromere_____