Chapter 2 Cells

READINGS

Chapter Opener
Diagnosis from a Tooth

Clinical Connection 2.1
Inborn Errors of Metabolism Affect the Major Biomolecules

Clinical Connection 2.2
Faulty Ion Channels Cause Inherited Disease

In Their Own Words
A Little Girl with Giant Axons

Bioethics: Choices for the Future
Banking Stem Cells: Is It Necessary?

CHAPTER OVERVIEW

Chapter 2 explores the components of human cells, how cells are replaced and specialize as an organism grows and develops, and how certain inherited diseases and cancer manifest at the cellular level. Organelles, which are unique to eukaryotic cells, function as compartments that establish microenvironments for specific functions and may sequester enzymes involved in related biochemical reactions that might otherwise damage the cell. Organelles form from aggregates of macromolecules (proteins, lipids, carbohydrates, and nucleic acids). The cell membrane controls what enters and leaves a cell, and interaction between the cell membrane and the cytoskeleton sculpts cellular architecture. Development of multicellular organisms requires cell growth and division (mitosis), as well as cell death (apoptosis). Stem cells are crucial in the formation of specialized (differentiated) cells during embryonic development and in the repair and replacement of tissues to maintain health. Stem cells persist in many adult tissues and have the potential to replace injured or diseased tissue. Researchers are investigating uses of stem cells to replace or rejuvenate injured or diseased tissue. The human body also includes many bacterial cells, which are collectively called the microbiome.

CHAPTER OUTLINE

2.1 Introducing Cells

1. Understanding how the trillions of cells in the human body function and interact reveals how they contribute to health and disease.
2. Somatic cells are diploid and contain two copies of the genome.

3. Gametes (sperm and egg cells) are haploid.
4. Stem cells, which are diploid, can reproduce and differentiate to replace dead or damaged cells.
5. Cell number and interactions maintain health.

2.2 Cell Components

1. All cells respond to the environment and use energy to power specialized functions, such as reproduction and movement.
2. Three broad varieties of cells are based on their complexity: Eubacteria (most known bacteria), Archaea (less well understood microorganisms), and Eukaryotes (complex cells, including our own.)
3. The Archaea and Eubacteria are similar in that they are single-celled, but they differ in certain features of their RNA and membranes. These cells lack nuclei and other organelles and therefore are prokaryotes. Although simpler than eukaryotic cells, the prokaryotes have existed longer and are therefore very successful life forms.
4. Eukaryotic cells have abundant and diverse organelles that compartmentalize biochemical reactions.

Chemical Constituents

1. Cells are constructed from molecules of all sizes. Many of the molecules of life are large. These macromolecules combine and interact to form larger structures within cells, such as membranes.
2. The building blocks of cells include carbohydrates (simple sugars and polysaccharides), amino acids and proteins, lipids (fats and oils), and nucleic acids (DNA and RNA).
3. Enzymes are proteins that catalyze biochemical reactions.

Organelles

1. Organelles establish compartments in the cell where specific functions take place, such as energy acquisition and secretion.
2. The nucleus (the storehouse of most of the DNA) has a double membrane and nuclear pores, which allow macromolecules in and out.
3. The outer boundary of the cell is the plasma membrane.
4. The cytoplasm is the portion of the cell outside the nuclear membranes and inside the plasma membrane. The cytoplasm contains organelles and diverse molecules.
5. The rough endoplasmic reticulum (ER), smooth ER, and Golgi apparatus function as a membrane network for the synthesis of proteins and lipids that are targeted for delivery to the plasma membrane, organelles, or for secretion.
6. Protein secretions bud off the ER in vesicles and travel to the Golgi apparatus for further processing. Lipids are exported from the ER without a vesicle.
7. Lysosomes contain enzymes that degrade cellular debris. This is termed autophagy.
8. Peroxisomes house enzymes that detoxify certain substances, break down lipids, and synthesize bile acids.
9. A mitochondrion has a double membrane whose inner folds carry enzymes that catalyze reactions that extract energy from nutrients.

Biological Membranes

1. The plasma membrane surrounds the cell and regulates which molecules enter and leave. Other membranes surround organelles or form them.
2. The framework of a biological membrane is a phospholipid bilayer, which forms because individual fatty acids have hydrophobic and hydrophilic portions.
3. Proteins, glycoproteins, and glycolipids embedded in, traversing, or protruding from either face of the phospholipid bilayer of a membrane function as enzymes, signal transduction receptors, transport proteins, and cell adhesion proteins.

The Cytoskeleton

1. The cytoskeleton gives a cell its specific architecture.
2. The major cytoskeleton components include microtubules (tubulin), microfilaments (actin), and intermediate filaments (a family of closely related proteins).
3. Microtubules form cilia (which may be motile or primary) and flagella.

2.3 Cell Division and Death

1. Health requires a balance of mitosis (the process by which chromosomes duplicate and separate), cytokinesis (the process by which the cell divides), and apoptosis (programmed cell death).

The Cell Cycle

1. The cell cycle consists of interphase, when a cell is not dividing, and mitosis.
2. The duplication and division of mitosis and cytokinesis maintains chromosome number.
3. Meiosis and cytokinesis produce gametes (sperm and egg), which have one set of chromosomes.
4. During interphase, proteins, lipids, and carbohydrates are produced in the G_1 phase; DNA and proteins are made during S phase; and more proteins are produced in G_2.
5. Replicated chromosomes have two sister chromatids attached at their centromeres.
6. Non-dividing cells may arrest during interphase and enter a quiescent phase (G_0).
7. In mitotic prophase, replicated chromosomes condense, a spindle forms, and the nuclear membrane breaks down.
8. In metaphase, chromosomes align down the center of the cell.
9. In anaphase, centromeres part and one chromatid from each pair is pulled to opposite ends of the cell.
10. In telophase, the cell pinches in the middle (cytokinesis), and the two new cells separate.
11. The cell cycle is tightly controlled and regulated at several “checkpoints.”
12. A cellular clock that limits the number of divisions is based on shrinking telomeres (chromosome tips).
13. Crowding, hormones, and growth factors are extracellular influences on mitosis.
14. Within cells, kinases and cyclins activate genes whose products carry out mitosis.

Apoptosis

1. Mitosis (cell division) and apoptosis (cell death) are continuous processes that are responses to signals in the extracellular environment.
2. Apoptosis begins with a signal to a death receptor, which activates enzymes called caspases to start cutting cell parts, including mitochondria, the cytoskeleton, and DNA. Pieces are wrapped in membrane, and phagocytes dismantle the destroyed cell.
3. Cell division and death are balanced to maintain tissues in growth, development, and repair. In prenatal development, coordination of these processes sculpts body form. After birth, mitosis and apoptosis protect and maintain the body.
4. Disruption of the balance between cell division and cell death can lead to cancer or other disorders.

2.4 Stem Cells

Cell Lineages

1. Stem cells are non-specialized cells that retain the potential to self-renew, yielding other stem cells as well as generating daughter progenitor cells that are capable of differentiating down any of several developmental pathways.
2. A fertilized egg is totipotent, able to produce any cell type.
3. Later in development, pluripotent stem cells give rise to progenitor cells that are committed to a particular pathway.
4. Stem cells persist in many adult tissues and have the potential to replace injured or diseased tissue.
5. Researchers are investigating uses of stem cells to replace or rejuvenate injured or diseased tissue.

Stem Cell Sources

1. Embryonic stem (ES) cells form in a laboratory dish from cells sampled from the inner cell mass of an early embryo. They come from existing embryos or can be derived using somatic cell nuclear transfer. Culture conditions guide differentiation of ES cells along particular differentiation pathways.
2. Induced pluripotent (iPS) cells are derived from somatic cells exposed to specific combinations of chemical factors. The cells are reprogrammed to assume different fates.
3. “Adult” stem cells are normally part of the body.

Stem Cell Applications

1. Stem cells are used to test new drugs, to model the earliest stages of disease, and to create tissue implants and transplants. A fourth application may be to reveal how we can directly alter stem cells in the body to treat disease.

2.5 The Human Microbiome

1. Non-human cells within and on us constitute the human microbiome. These cells greatly outnumber our own.
2. We share a “core microbiome” but differ in other microbial species depending upon our genomes, environments, and health.
3. Different body parts harbor distinct microbiomes.
4. Probiotics and fecal transplantation alter the microbiome to prevent or treat certain conditions.

IDEAS FOR CLASSROOM DISCUSSION

1. Have students contribute the names of bacteria and viruses that are in the news, such as *E. coli*, *Salmonella*, Ebola virus, hepatitis viruses, and influenza viruses. Compare and contrast the structures of these pathogens. Is there a correlation between the complexity of a microorganism or virus and the effect it can have on a human body? How do bacteria, viruses, and human cells differ?
2. Discuss the functions in the human body of specific biochemicals, such as salivary amylase, cholesterol, myosin, epinephrine, glycogen, hemoglobin, and interleukins.
3. If students were to build a synthetic human, what materials might they use to mimic the structure and/or function of the four basic tissue types?
4. Choose a secretion and describe how its components are produced and assembled at the cellular level.
5. Choose an organelle or other subcellular structure and describe an inherited disease that results from its malfunction.
6. Ask students to bring in print ads for skin care products that claim to be “anti-aging” or increase cell division in the skin. Discuss why the first claim is impossible, and the second could be dangerous.
7. “Stem cell tourism” is the marketing of stem-cell-based treatments that have not been adequately tested in controlled clinical trials. Have students bring in examples of such services, try to explain what exactly is being offered, and why the treatment might not work. Identify dangers of manipulating cell division.

DNA SCIENCE BLOG POSTS (http://blogs.plos.org/dnascience/)

Wilson Disease – A Genetic Success Story
http://blogs.plos.org/dnascience/2014/07/03/wilson-disease-genetic-success-story/
(A nurse read Clinical Connection 2.1 and recognized Ingrid, the woman with Wilson disease, as an ex-patient!)

ALS Target: Microglia
http://blogs.plos.org/dnascience/2014/08/06/new-als-target-microglia/

Getting to the Bottom of Fecal Transplants
http://blogs.plos.org/dnascience/2014/06/26/getting-bottom-fecal-transplants/

Eliza’s Journey: Part 1 (a lysosomal storage disease)
http://blogs.plos.org/dnascience/2014/05/29/elizas-journey-part-1/

ALS Treatment (in Cells) – Too Late for Glenn, But Wonderful News
http://blogs.plos.org/dnascience/2014/04/03/als-treatment-late-glenn-wonderful-news/

Mitohype: 3-Parent Designer Babies Who Will Change Human Evolution
http://blogs.plos.org/dnascience/2014/03/06/mitohype-3-parent-designer-babies-revisited/

Patient-Specific Stem Cells Recapitulate Age-Related Macular Degeneration
http://blogs.plos.org/dnascience/2014/02/13/patient-specific-stem-cells-recapitulate-age-related-macular-degeneration/

10 Reasons Why Growing a Human Brain-in-a-Dish Is Terrific
http://blogs.plos.org/dnascience/2013/08/28/10-reasons-why-growing-a-human-brain-in-a-dish-is-terrific/

A Little Girl with Giant Axons
http://blogs.plos.org/dnascience/2013/05/16/a-little-girl-with-giant-axons-a-deranged-cytoskeleton-and-gene-therapy/

Retinal Stem Cells and Eye of Newt
http://blogs.plos.org/dnascience/2013/01/17/retinal-stem-cells-and-eye-of-newt-3/

The Crud: Viral or Bacterial?
http://blogs.plos.org/dnascience/2013/01/10/the-crud-viral-or-bacterial/

Cialis Comes Full Circle: Help for Muscular Dystrophy
http://blogs.plos.org/dnascience/2012/11/28/cialis-comes-full-circle-help-for-muscular-dystrophy/

Mice with Human Liverlets Test New Drugs
http://blogs.plos.org/dnascience/2012/11/15/mice-with-human-liverlets-test-new-drugs/

Human Embryonic Stem Cells Finally Reach Clinical Trials: Maurie's Story
http://blogs.plos.org/dnascience/2012/09/27/human-embryonic-stem-cells-finally-reach-clinical-trials-mauries-story/

WEBSITES

1. *Online Mendelian Inheritance in Man* (www.omim.org) *is* a searchable database and a source for information on the various genetic disorders discussed in the text, including family histories, clinical descriptions, pattern of inheritance, and molecular information.

2. Genetests.org has articles on specific inherited conditions.

3. The Cell: An Image Library (http://www.cellimagelibrary.org/) displays many different cell types.

4. The International Society for Stem Cell Research (http://www.isscr.org) and the Coriell Institute for Medical Research (http://www.coriell.org/) have information on all types of stem cells and their applications.

ANSWERS TO REVIEW QUESTIONS

1. a. 4 b. 6 c. 2 d. 1 e. 7 f. 3 g. 5

2. a. Sanfilippo syndrome (mucopolysaccharidosis type IIIA) affects a lysosomal enzyme, causing irreversible brain damage, affecting speaking and mobility, causing seizures, and leading to death in early adolescence.
   b. Adrenoleukodystrophy causes brain degeneration due to a mutation in a gene that encodes a protein important in regulating transport of substances in and out of peroxisomes (see p. 23).
   c. Section 5.2 describes a mitochondrial myopathy.
   d. GAN ("In Their Own Words" on page 28) is a disease affecting the cytoskeleton (intermediate filaments). Cancers also affect the cytoskeleton (microtubules).
   e. Cystic fibrosis (Clinical Connection 2.2) is the result of a misfolded chloride channel.

3. Compartmentalization separates biochemicals that could harm certain cell constituents. It also organizes the cell so it can function more efficiently.

4. The plasma membrane mediates signal transduction and cellular adhesion.

5. Hormones, growth factors, cyclins, and kinases

6. Specialized cells express different subsets of all the genes that are present in all cell types, except for red blood cells (which lack nuclei).

7. a. A bacterial cell is usually small and does not have a nucleus and other organelles. A eukaryotic cell contains membrane-bounded organelles, including a nucleus, that compartmentalize biochemical reactions.
   b. During interphase, cellular components are replicated. During mitosis, the cell divides, distributing its contents into two daughter cells.
   c. Mitosis increases cell number. Apoptosis eliminates cells.
   d. Rough ER is a labyrinth of membranous tubules, studded with ribosomes that synthesize protein. Smooth ER is the site of lipid synthesis.
   e. Microtubules are tubules of tubulin and microfilaments are rods of actin. Both form the cytoskeleton.
   f. A stem cell has greater developmental potential than a progenitor cell.
   g. A totipotent cell can differentiate as any cell type; a pluripotent cell's fates are more restricted.

8. Intermediate filaments are similar to microtubules and microfilaments in that they are all composed of protein subunits. They differ in size and protein composition. Microfilaments are the smallest, and are composed mainly of actin. Microtubules are the largest, and are mostly tubulin. Intermediate filaments are intermediate in size and are of several types, each assembled from distinct proteins.

9. *The New York Times*, May 15, 2013: "Embryonic stem cells can turn into any type of cell in the body …" If ES cells all turned into differentiated cells, the stem cell culture could not sustain itself.

10. Embryonic stem (ES) cells are pluripotent cells from the inner cell mass of a very early stage embryo or derived from somatic cell nuclear transfer. Induced pluripotent stem (iPS) cells are pluripotent cells created from non-pluripotent somatic cells

through genetic manipulation. Adult stem cells are found throughout the body from embryonic development onward. They can divide and yield differentiated daughter cells and are important for cell replacement. Pros and cons: ES cells are naturally pluripotent and self-renewing. Use of hES cells is more controversial than that of iPS cells or adult stem cells and countries vary in their policies regarding such research. The full potential of iPS and adult stem cells is not yet known. Adult stem cells are multipotent rather than pluripotent. Potential risks involve rejection of implanted somatic cells and causing cancer.

11. The microbiome is the population of non-human cells living in a human body.

12. Removing the bacteria that normally live in the human body can be very dangerous, because many are required in our physiology, such as digestion.

13. The human genome and the microbiome are similar in that they both account for the DNA in our bodies. They are different in that the DNA in the microbiome is within prokaryotic cells, and our (human) DNA is in eukaryotic cells.

ANSWERS TO APPLIED QUESTIONS

1. a. Lack of cell adhesion can speed the migration of cancer cells.
   b. Impaired signal transduction can block a message to cease dividing.
   c. Blocking apoptosis can cause excess mitosis, and an abnormal growth.
   d. Lack of cell cycle control can lead to too many mitoses.
   e. If telomerase is abnormal, a cell might not stop dividing when it normally would.
   f. A stem cell activated to divide would increase cell number.

2. Mitochondria

3. Peroxisome

4. A sodium channel regulates the movement of sodium into and out of cells. It is found in the plasma membrane.

5. Lysosome

6. Cells in an embryo are rapidly dividing, not in a resting state.

7. A lysosomal storage disease results from deficiency or absence of an enzyme that normally breaks down a specific biochemical. Providing the enzyme can reinstate that function. Umbilical cord stem cells from an unaffected individual can provide cells that produce the needed enzyme, but must do so in a way that reaches the affected area.

8. Induced pluripotent stem cells come from a person's somatic cells, such as skin fibroblasts. Adult stem cells are naturally found in the body.

9. a. Pluripotent b. adult stem cells

10. Different microbiomes

ANSWERS TO WEB ACTIVITIES

1. Answers vary with website selected

2. Ciliopathies

ANSWERS TO FORENSICS FOCUS

1. DNA profiling could be used to see which illegal products shared DNA sequences with relatives. For example, the sibling of a victim would share half of DNA sequences from his or her white blood cells or cheek lining cells with the DNA in bone, because the genomes are the same in different tissues of the same body.

ANSWERS TO CASE STUDIES AND RESEARCH RESULTS

1. Her cells cannot break down a specific type of molecule in her lysosomes, and so the material accumulates, impairing cell functions. Taylor can no longer hear and has to be fed with a tube.

2. Identify a group of men and measure the rate of telomere shrinkage at a time when stress is minimal (perhaps sophomore year of college) and then again at a more stressful time (first year after college), and record their perceptions of their comparative stress at both times.

3. Hannah's own cells would give her the disease all over again.

4. This is a study of both metagenomics (the bacteria in a given physical location) and the human microbiome (bacteria that got in the restroom from body parts).

5. a. Researchers can develop drinks of bacteria that would enable children to maximize the nutrients that they can use from foods.
   b. The study allowed malnutrition to happen, but attempted to be ethical by providing the healthy diet as soon as one twin became ill.
   c. Identical twins following the same diet can differ in nutritional status if the bacteria in their digestive tracts differ in ways that affect nutrient absorption.

ANSWERS TO CLINICAL CONNECTION 2.1 QUESTIONS

1. Inherited diseases may disable enzymes that catalyze reactions that synthesize or break down molecules that are not proteins, such as lipids and carbohydrates.

2. Enzymes are very diverse; they catalyze many different biochemical reactions in the human body.

3. Treatment for lactase deficiency is dietary; avoiding the sugar that the infant cannot digest. Statin drugs can lower serum cholesterol in familial hypercholesterolemia. Treatment for maple syrup urine disease is dietary; avoiding the three amino acids that the infant cannot digest. Biotin supplements are used to treat biotinidase deficiency. The drug penicillamine enables a person with Wilson disease to excrete some of the excess copper.

ANSWERS TO CLINICAL CONNECTION 2.2 QUESTIONS

1. A channelopathy affects an ion channel embedded in a plasma membrane.

2. In inability to feel pain, sodium channels do not transmit pain signals. In conditions that cause intense pain, sodium channels are extra sensitive or remain active for too long.

3. Abnormal potassium channels cause diverse symptoms because they are found in different cell types.

4. Protein misfolding

ANSWERS TO BIOETHICS: CHOICES FOR THE FUTURE

1. Stem cell banks might be regulated the same way that blood banks or tissue banks are, or perhaps as medical devices.

2. The web sites should state not just that stem cells can be used to treat a disease, but that they must come from a healthy donor.

3. Opinion about how much information a for-profit organization should provide when seeking clients. Incomplete information may take advantage of consumers who do not know much about genetics.

4. DNA can be taken from cheek lining cells or from white blood cells of a child.

ANSWERS TO KEY CONCEPTS QUESTIONS

2.1

1. Symptoms arise from events at the cellular level.
2. Diploid cells have two copies of the genome. Haploid cells have one copy.
3. A somatic cell is diploid; a “body cell.” A germ cell is haploid; sperm or egg.

2.2

1. Cells contain complex structures built of proteins, carbohydrates, lipids, nucleic acids, and many types of smaller molecules.
2. Organelles subdivide cell functions by enclosing enzymes with related functions within membrane-bounded structures, such as the Golgi apparatus and ER.

3. The plasma membrane provides a surface that includes receptors and passageways through which substances (such as signaling molecules and cell adhesion factors) bind or move.
4. The cytoskeleton is an inner framework of protein rods and tubes that supports a cell, gives it shape, and enables movement.

2.3

1. Mitosis is the division of somatic cells. Apoptosis is programmed cell death.
2. If mitosis and apoptosis are not in balance, body parts will have too many or too few cells to maintain health.
3. The cell cycle is divided into interphase, when cellular components are replicated, and mitosis, when contents are distributed into 2 cells. Mitosis is divided into 4 stages: prophase (chromosomes condense), metaphase (chromosomes align); anaphase (chromosome sets part); telophase (separation of chromosome sets completes). Cytokinesis occurs at the end of mitosis and separates the duplicated chromosomes into two distinct daughter cells.
4. Telomere length, hormones, growth factors, cyclins, and kinases control the cell cycle.
5. During apoptosis, a signal activates a cell surface death receptor, and then caspases tear apart cell structures. Remnants are neatly packaged into pieces of membrane and finally phagocytes dismantle the debris.

2.4

1. Self-renewal and generation of daughter cells that specialize (or whose daughter cells do so).
2. Stem cells self-renew but progenitor cells do not.
3. Cells differentiate down lineages by expressing different subset of genes.
4. Stem cells enable the body to produce new cells, which is important in growth and repair of injured tissue.
5. Embryonic stem cells are derived in laboratory glassware from inner cell mass cells of an early embryo or via somatic cell nuclear transfer. Induced pluripotent stem cells are derived from somatic cells that are treated with specific factors that cause them to become less differentiated, and then additional factors guide their differentiation. Adult stem cells are naturally-occurring somatic cells.
6. Stem cells can be used to augment or replace damaged or diseased cells. They are also useful in drug discovery and in studying the earliest stages of diseases, particularly for types of cells that do not divide.

2.5

1. The human microbiome is all of the species of bacteria in a human body.
2. Armpit, groin, anus, intestines, mouth, vagina, penis
3. The microbiome affects how many calories we extract from nutrients, susceptibility to infection, and effectiveness of certain drugs. Microbiome imbalances are present in many diseases, but it isn't always clear whether the changes are a cause or an effect of the illness.
4. Metagenomics is the study of all of the microbial life in a defined region, from as large as the biosphere to a termite's gut.

ADDITIONAL QUESTIONS

1. Severe childhood autosomal recessive muscular dystrophy, prevalent in North Africa, affects both sexes and is caused by a deficiency of a dystrophin-associated glycoprotein called adhalin. Explain how mutations in two different genes those for dystrophin and adhalin can cause the same symptoms of muscle wasting.

2. A science fiction plot is to activate telomerase so that people do not age at the cellular level. Might this strategy work, have no effect, or be harmful? Explain your answer.

3. Achondroplasia is the most common form of inherited dwarfism (see figure 5.1). The causative gene encodes a protein receptor on surfaces of bone and cartilage cells that normally binds a growth factor. Explain how an abnormal form of this gene might cause dwarfism.

4. Match the disorder on the left to the process or structure on the right that is abnormal. A disorder can match more than one process or structure, and vice versa.

a. Tay Sachs disease	1. peroxisome
b. giant axonal neuropathy	2. microbiome
c. cancer	3. apoptosis
d. cystic fibrosis	4. lysosome
e. Bardet-Biedl syndrome	5. intermediate filaments
f. adrenoleukodystrophy	6. cilia
g. polycystic kidney disease	7. mitosis
h. sunburn peeling	8. mitochondria
i. obesity	9. ion channel

5. Search under “stem cells” at clinicaltrials.gov. Select a clinical trial protocol and describe the type of stem cell being tested, and the condition it is being evaluated to treat.

6. Explain how a genetic disease can be diagnosed from extracting and testing DNA obtained from a blood sample as well as from a different tissue, such as the tooth described in the chapter opener.

ANSWERS TO ADDITIONAL QUESTIONS

1. The two proteins function together to maintain muscle cell integrity, so when either is abnormal, the result can be muscle weakness.

2. Activating telomerase could lead to inappropriate cell division (cancer) and would not counter aging, which is biological change associated with the passage of time.

3. Bone and cartilage cells in people with achondroplasia do not receive sufficient signals to divide and, therefore, do not produce enough cells to build bones to normal size.

4. a. 4 b. 5 c. 3 and 7 d. 9 e. 6 f. 1 g. 6 h. 3 i. 2

5. More than 4,600 trials are listed. Examples include fat stem cells to treat erectile dysfunction, corneal stem cells to treat blindness, neural stem cells to treat amyotrophic lateral sclerosis, and mesenchymal stem cells to treat knee osteoarthritis, rejection of transplants, and ulcerative colitis.

6. White blood cells and tooth cells of an individual contain the same genome.