LESSON 2:
Why Use Animals in Research?

INTRODUCTION

Students begin this lesson by watching video vignettes exploring the "3 Rs" (*Replacement*, *Reduction*, and *Refinement*), which guide scientists in conducting humane research with animals. Student groups are then introduced to several types of models, including **model organisms**, which scientists may use to answer different types of research questions. Using a set of Research Model Cards, students explore research questions and evaluate possible methods to determine the most appropriate **model** for answering the research questions.

KEY CONCEPTS

- The 3 Rs (*Replacement*, *Reduction*, and *Refinement*) guide scientists in conducting humane research with animals.
- Our views on the use of animal models in research can be informed by understanding the purpose of the research, the different methods available for testing research questions, and the importance of using the appropriate model for collecting the strongest evidence.
- Some models are more appropriate than others for answering research questions. Many questions cannot be satisfactorily answered without the use of whole organisms.
- Scientific research is conducted for a variety of reasons, such as:

  a) to increase scientific understanding (basic research).

  b) to develop treatments for medical conditions.

  c) to evaluate the toxicity of different compounds that humans use (medicinally or cosmetically).

LEARNING OBJECTIVES

Students will know:

- The definitions of the 3 Rs (*Replacement*, *Reduction*, and *Refinement*).

Students will be able to:

- Apply the 3 Rs to scientific research.
- Identify the purpose and importance of various scientific questions.
- Identify the appropriate models needed for answering various scientific questions.
- Understand the importance of using animal models to answer various scientific questions.

CLASS TIME

Two to three class periods of 50 minutes each.

MATERIALS

Materials	Quantity
Student Handout 2.1—*Research Model Cards Summary Table*	1 per student
Student Handout 2.2—*Research Topics*	1 per group or used as a class overhead
Student Handout 2.3—*Alzheimer's Disease*	Enough for each student in each group to get one (i.e. for a class of 30 split into 5 groups, 6 copies of each handout would be needed).
Student Handout 2.4—*Type II Diabetes*	
Student Handout 2.5—*Male Pattern Baldness*	
Student Handout 2.6—*Antibacterial Soap*	
Student Handout 2.7—*Spinal Cord Injury*	
Teacher Resource 2.1—*Answer Key for Research Model Cards Summary Table*	1
Teacher Resource 2.2—*Questions for Use with Research Model Cards*	1
Teacher Resource 2.3—*Possible Answers for Research Questions*	1
Teacher Resource 2.4—*Master Copy for Research Model Cards*. Each group will need a complete set of cards (copy these back-to-back).	1 set per group

FRAMING THE LESSON

While Lesson Two focuses on the use of appropriate animal models to answer specific research questions, it may be helpful for students to know that biomedical research depends on animal models in four general categories:

1. **To advance scientific understanding:** Scientists need a fundamental understanding of the body in both health and illness before new drugs and therapies can be applied to human disease. Basic research done today may be the foundation of treatments in the future. Transgenic organisms, especially mice, have been useful in both basic research and as disease models.

2. **Models to study disease:** Some animals have naturally-occurring diseases that also affect humans (cats get diabetes, for example) and some animals are purpose-bred to have specific diseases or conditions (i.e. mice induced to have cystic fibrosis). Both types can be used as animal models in order to study how disease affects the body.

3. **Models for new medical treatments, devices and techniques:** Once scientists have an idea about how to best treat a disease or improve a condition, the concept is tested on animals before being tested in humans. This applies to new medications, medical devices such as a new heart valves or knee replacements, and new surgical procedures.

4. **Safety testing:** The Food and Drug Administration (FDA) requires that new medicines be tested for safety and effectiveness in two species before they are tested in humans. Researchers must account for how the drug is absorbed, distributed, metabolized, and excreted (referred to as ADME testing) in a living system. More information about alternatives to using animals in safety testing can be found as an extension to this lesson.

TEACHER PREPARATION

- Make copies of Student Handouts.
- Make a set of Research Model Cards for each student group. Using Teacher Resource 2.3—*Master Copy for Research Model Cards*, copy the cards back-to-back and then cut them to create separate cards.

PROCEDURE

ACTIVITY ONE: WHAT ARE THE 3 Rs?

1. Tell students that the aim of this lesson is to a) have them become more familiar with the 3Rs that guide scientists in conducting humane research with animals, and b) learn about how animal models are used in research.

2. Review with students the 3 Rs, introduced in Student Homework 1.1—*Animal Research: The Need for a Middle Ground*. Make sure students have an understanding of what each "R" stands for and how it can be applied. Below are some questions that pertain to each "R:"

   - **Replacement**

     a) Can the animal model be replaced by another type of model, such as a cell culture, **computer model**, or tissue culture?

     b) Can a lower organism be used to replace a higher one? For example, can zebrafish or fruit flies be used instead of rodents to study the effects of genetic mutation?

   - **Reduction**

     a) What is the fewest number of animals that can be used in a research project and still gain statistically significant results (to demonstrate that the results of the research are from a direct cause and not just by chance)?

     b) How can researchers get the same amount of data from fewer animals?

   - **Refinement**

     a) How can techniques and procedures be refined so as to avoid animal suffering? For example, what is the best type of pain relief medication to give a rodent after surgery?

     b) How can the lives of research animals be enhanced through shared housing, social enrichment, or diet?

3. Go to the Understanding Animal Research website to access the interactive "What R You Watching?" video set.

   Understanding Animal Research: What R You Watching? Videos
   http://www.understandinganimalresearch.org.uk/schoolzone/rights_and_wrongs/

4. Choose one or more of the six short videos (each is less than three minutes long) to show students. Each researcher-narrated vignette illustrates one of the 3 Rs. A one-question quiz is built into the website. Have students guess which "R" is applied in each case before revealing the answer.

ACTIVITY TWO: INTRODUCING THE RESEARCH MODEL CARDS

5. Introduce the concept of a "model" to students. Ask students, "When I say the word ***model***, what do you think of?" In some cases, students may think models represent the ideal, such as fashion models, or model students.

6. Explain that there are different types of models, including physical models, mental models, and conceptual models—which includes mathematical and computer models. Discuss models that are actual physical constructions. Have students point out science models in the classroom (i.e. a model of DNA, the solar system, or human body systems), if available. Ask students about the strengths and weaknesses of using these different models. Point out that each model represents the "real thing" when working directly with the object is not feasible (i.e. DNA is too small, the solar system is too large, and using a human body to study human body systems is not practical or ethical.)

7. Point out that scientists involved in biomedical research use models too—they could be computer models, animal models, cell or tissue cultures, or other types of models. Models are used to help scientists understand how the "real thing" works. With the goal of much biomedical research being to find cures and treatments for human disease, the "real thing" is usually a human being. The use of models adds to the understanding of how human systems work.

8. Tell students that all model organisms, including animal models, are used, on some level, ***to study human disease and function when using humans is not feasible.*** However, in the case of medications, medical devices, or medical treatments, final testing will be conducted on humans after safety and efficacy has been demonstrated on animal models. Most model organisms have traits in common. A useful model organism tends to be:

- Small.
- Able to reproduce rapidly with many offspring.
- Inexpensive to house and maintain.
- Able to be manipulated genetically on the molecular level.
- Well-studied by other scientists.

9. Point out to students that many model organisms have had their genomes completely sequenced, meaning scientists have determined the exact order of the base pairs (A, T, C, G) in the genome from a representative of that species. This, in turn, gives scientists information about the genes found in that species and allows them to ***compare gene sequences*** between species. This work involves a high level of collaboration between scientists.

10. Divide the class into groups. Ideally, you will have five student groups. Give each group a set of the *Research Model Cards*.

11. Explore the cards with students to identify words they do not understand or unclear concepts such as **transgenic organisms** or **sequenced genome**. Use the parenthetical definitions on the cards, as well as the ***Glossary*** section in this lesson plan, to help students understand new terms and concepts.

12. Give the groups about three to five minutes to look through the cards.

13. Have students examine the photographs of the animals on the cards. For pictures of all the vertebrate animals, tell students that these are pictures of actual research animals in a laboratory situation. They are not "pets" or living in their natural habitat.

14. Introduce students to the types and uses of organisms on the Research Model Cards by asking them questions using Teacher Resource 2.2—Questions for Use with Research Model Cards. Since students are already in groups, the questions could be the basis for a team game if desired. After the teacher poses a question, the first team to write down and share the correct answer wins a point. If no teams give the correct answer, the teacher may read the included hint. The team with the most points at the end of the game may get first choice of which research topic they want to pursue in *Activity Three*. Encourage thoughtful guesses, since this will most likely be new information for students.

The use of the words "lower" and "higher" when describing types of living organisms reflects an obvious bias which should be acknowledged. Even a single yeast cell shows amazing complexity and shares many cellular processes with humans. However, the concerns about killing yeast when baking bread, for example, do not trigger the same level of ethical concern as the harming of higher animals that are more neurologically developed.

15. Challenge each group to sort their Research Model Cards so that they are roughly in order from **lower organisms** or models to **higher organisms** or models. "Lower" organisms are those for which there is less ethical concern about their use due to their level of neurological development or complexity (There might be several cards on the same level of complexity.) In working to *Replace* higher organisms with lower organisms (one of the principles of the 3 Rs), scientists are moving towards using lower organisms such as zebrafish and *C.elegans* worms to replace research with rodents when possible.

16. Distribute copies of Student Handout 2.1—*Research Model Cards Summary Table*, one per group. Challenge each group to work as a team to complete the table by placing a check mark in the column that best represents a potential use for that organism. This summary table will be a helpful tool for students to use when completing the next activity.

ACTIVITY THREE: CHOOSING THE RIGHT MODEL FOR THE RIGHT RESEARCH QUESTION

17. Discuss the "Your Reaction to its Use" section of the table. Students may want to acknowledge a unique understanding or familiarity with different animals in the model card set. For example, a student who has had frogs as pets may react differently than a student without much experience with frogs. Generally, student reactions will change based on the complexity of an organism as well as that student's familiarity with an organism.

    If a student's reaction is to state, for example, "Dogs should never be used in research" then ask the student to explain his or her reasoning in writing on the handout. Additional points can be found on Teacher Resource 2.1.

18. Distribute one copy of Student Handout 2.2—*Research Topics* to each student group, or create one overhead for the class to use as a group. Ask the students to cooperatively read the background information and research goals for each of the five topics presented on the Student Handout (**Alzheimer's Disease**, **Type II Diabetes**, **Male Pattern Baldness**, **Antibacterial Soap**, and **Spinal Cord Injury**).

19. Ask students, ***"Are all of these research goals equally beneficial?"*** If the funding agency has a limited amount of funds, should each study be funded? If only three could be funded, which would they be? If more money became available, what would the fourth study be? Consider that even a study that might seem low priority (i.e. male pattern baldness) could have unforeseen benefits in other areas, such as the treatment of other genetic skin conditions, or helping patients grow hair lost through chemotherapy treatments.

20. Tell students that an overarching Research Question ("How can we cure Alzheimer's?") is really answered by asking many smaller questions, such as, "How do **neurons** work?" or "Which parts of our brain work to give us memory?" Different research models may be used to answer different types of questions at various points in the research process. It may take years of **basic research** ("How do neurons work?" or "How do neurons communicate?") before an idea for a drug or treatment is ready to test in a living organism. This basic research may (or may not) benefit Alzheimer's patients and people with other types of neurological conditions in years to come.

21. Explain to students that researchers must carefully choose their models in order to collect reliable, accurate results and that they are required to follow regulations about the care and use of their animal subjects.

22. Distribute one copy of Student Handouts 2.3 - 2.7 to each student group, so that each group is given a different research topic (Alzheimer's Disease, Type II Diabetes, Male Pattern Baldness, Antibacterial Soap, and Spinal Cord Injury). If the class has fewer than five groups, only hand out the topics the class decided were the most important. If the class has more than five groups, make additional copies of one or more of the handouts.

23. Once the student groups receive the Student Handout featuring their research topic, they should:

- Put aside any of the Research Model Cards that will not be useful to them in answering the questions.
- Choose which models they think can best help answer the Research Questions.
- Of the models they have chosen, put the cards in order from lowest organism or model to highest organism or model (some cards might be at the same level).
- Answer the questions on the Student Handout.

[***Note:*** Each of the three questions on the Student Handouts 2.3 – 2.7 generally corresponds to a different point in the research process. Further notes are available on Teacher Resource 2.3—*Possible Answers to Research Questions*.]

24. Tell students that many different models may work to answer the same question—there is no one right answer. Groups should be prepared to explain why they thought one model would be better than another model.

25. During group work time, the teacher should move from group to group monitoring the discussions, reminding students of the 3 Rs, and making sure the subjects they choose are appropriate.

26. Students should then select a speaker to summarize their findings in a whole class discussion.

ACTIVITY FOUR: DEBRIEFING THE RESEARCH QUESTIONS

27. Provide time for each group to present their Research Question and their chosen model(s).

28. Ask the class, "Did any group use plants for their model organism?" Students should notice that plants will not work for any of the research questions. The teacher can emphasize that compounds often originate from plant sources but need to be tested on animals if they are to become a treatment. Otherwise plants are used mainly for agricultural studies.

29. Ask students, "Which of the 3 Rs were you using when ordering the cards? Why does this matter?" Students were using *Replace*, hopefully replacing animals such as primates or dogs with the lowest species available, or with a computer or cell culture model system.

30. Survey students again to see if all of the research questions seem equally important to them. Have students vote informally for what they think is the most important and the least important research question. Would any groups choose not to pursue the research?

CLOSURE

31. Check students' comprehension to be sure they realize that research using animals is not a "free for all" in which scientists randomly choose an animal subject. Instead, specific animals or models are chosen to answer specific questions asked at different times in the research process. The large research questions (i.e., "How do we cure Alzheimer's?" or "How do we cure diabetes?") are being asked collaboratively by thousands of scientists worldwide. Each scientist, however, may be working to answer a very small part of the larger question.

32. Review the 3 Rs (*Replacement*, *Reduction*, and *Refinement*) and ask students for examples of how each might be used.

33. Let students know that the use of the 3 Rs is a place of "common ground" between research scientists and animal rights activists.

HOMEWORK

- Students can explore the following website to learn more about model organisms.

WWW Virtual Library: Model Organisms
http://www.ceolas.org/VL/mo/

ADAPTATION

- Student groups could work with a number of different Research Questions by rotating each question to a new group every few minutes. Students could check the previous group's work, and add or change information as they proceed.

EXTENSION

What are the alternatives to using animals in safety testing?

The use of animals in safety and toxicity testing, specifically for chemicals used in cosmetics, has lead to vigorous public debate since the 1970s. While safety testing in animals is not required by law for cosmetics as it is for drugs, research organizations and drug companies have sought out alternative toxicity testing methods as guided by the 3Rs. Creating, verifying and incorporating alternative methods can take many years, as the alternatives need to be formally validated as being as accurate, or better than, the animal procedures they are replacing. The U.S. federal government supports the development of alternatives to animals through the Interagency Coordinating Committee on the Validation of Alternative Methods, or ICCVAM.

Some examples of alternative methods are:

- EPISKIN is a three-dimensional human skin model that can be used to assess topical applications. This model was developed by a company now owned by L'Oreal, the cosmetics corporation.
- Medical devices and injected compounds that come into contact with blood or cerebral spinal fluid must be tested to find out if they cause fever in humans. This test used to be done in rabbits by injecting the compound in question into the rabbit and seeing if a fever developed within twenty four hours. Now, researchers can use the "blood cells" (hemolymph) of a horseshoe crab to test for fever-inducing compounds, since the horseshoe crab blood reacts to the compounds that cause inflammation (and fever) in humans.
- Skin penetration or absorption tests that used to rely on living animals can now be done using a "Franz Cell." This is a vertical diffusion tube with an upper and a lower chamber. Skin left over from elective surgeries or donated through cadavers can be placed in the upper chamber and used to determine the rate and extent of penetration of a test compound.

Students can research alternative methods at the following websites:

ICCVAM: http://iccvam.niehs.nih.gov/about/ni_QA.htm

John Hopkins Center for Alternatives to Animal Testing: http://caat.jhsph.edu/

Non-Animal Methods for Toxicity Testing: http://www.AltTox.org

Additional information about alternatives to safety testing can be found at the end of Lesson 3 in the **Consumer Awareness** curriculum found at:

http://www.nwabr.org.

GLOSSARY

Alzheimer's Disease: A form of dementia, or loss of brain function, that gradually worsens over time and affects behavior, thinking, and memory.

Anti-inflammatory Drugs: Drugs used to treat inflammation. These drugs counteract the reactions caused by damaged cells, which release chemicals that stimulate the immune system, leading to swelling, and increase flow of cells to the damaged site.

Bacteria: Tiny, single-celled organisms. These prokaryote organisms lack a nucleus and organelles within the membrane of the cell. Bacteria can form an association with other organisms that cause them to become pathogens, which can cause human disease and death from infections such as cholera, diphtheria, tuberculosis, and tetanus.

Basic Research: Fundamental questions that are asked in order to enhance the knowledge base of a subject, rather than to cure a specific disease or condition.

Blood Glucose: Also called blood sugar, glucose is a simple sugar that is the basic fuel used by cells in the body. The blood glucose level is a measurement of glucose in blood.

Computer Model: A computer program which attempts to simulate the behavior of a system, generally through the use of a mathematical model.

Diabetes: A disease characterized by a person having a high blood glucose level and treated with injections of insulin and other medications. There are three main types of diabetes: Type I, Type II, and gestational diabetes, the latter of which only occurs in pregnant women.

Differentiation: The process by which a less specialized cell transforms into a more specialized type of cell.

Dosage: A prescribed amount of a medication.

Embryo: An organism at its earliest stages of development, after fertilization of the egg and first cell division. In humans, an embryo is the first eight weeks after fertilization, after which the developing organism is called a fetus.

Eukaryote: Any organism that has a nucleus and specialized organelles within its cell(s). All of the living Research Models are eukaryotes, except bacteria.

Genome: An organism's entire genetic information, encoded in either DNA or RNA (for many viruses). Scientists have been able to sequence the genome of some organisms.

Hair Transplant: A surgical treatment for male pattern baldness that involves taking hair follicles from a donor part of the body and transplanting it into a recipient part of the body (usually the scalp). The donor site is chosen based on the hair follicles' genetic resistance to balding.

Hereditary Condition: Also called a genetic disorder, a hereditary condition is a condition or illness caused by abnormalities in genes or chromosomes. The genetic defect can be inherited from an individual's parents and/or passed down to his or her children.

Informed Consent: In a research study with human volunteers, each research subject must be capable of understanding the facts and risks of the study, and the researchers must clearly relay this information. Informed consent is this exchange of information, followed by the volunteer providing their consent to participate in the study.

Insulin: A hormone that causes cells in the body to take glucose from the blood into the cells where it can be used.

Insulin Receptors: A receptor in the body that is activated by the presence of insulin, which causes uptake of glucose.

Lower/Higher Organisms: "Lower" organisms are those for which there is less ethical concern about their use due to their level of neurological development or complexity. "Higher" organisms are those for which there is more significant ethical concern about their use in research.

Male Pattern Baldness: A genetic condition that causes hair loss in a predictable pattern along the temples and crown of the head.

Microbe: Also called a microorganism, a microbe is one of a group of microscopic organisms that includes bacteria, fungi, archaea, protists, green algae, plankton, and planaria.

Model: A representation of a phenomenon, object, or idea. A model can be developed to represent a phenomenon, object, or idea using a more familiar one (like using an analogy).

Model Organism: An organism that is used in research because it is easier to study a particular aspect in that organism, rather than in humans and higher organisms. Model organisms tend to be small, able to reproduce rapidly with many offspring, inexpensive to house and maintain, able to be manipulated genetically on the molecular level, and well-studied by other scientists. Major model organisms include E. coli bacteria, yeasts, slime molds, fruit flies, zebrafish, and mice.

Neuron: Also called a nerve cell, a neuron is a specialized cell in the nervous system (brain, spinal cord, and nerves) that processes and communicates information through electrical and chemical signals.

Prokaryote: Any organism that does not have a nucleus or membrane-bound organelles, such as bacteria.

Quadriplegia: The result of a paralyzing injury that causes partial or total loss of the use of arms, legs, and torso, as well as the loss of sensory functions in these areas.

Reduction: One of the 3 Rs of animal research proposed by Russell and Burch. Reduction means using the fewest number of animals possible in a research project to gain statistically significant results.

Refinement: One of the 3 Rs of animal research proposed by Russell and Burch. Refinement means using any technique or procedure that decreases the suffering, or enriches the life of, an animal used in research.

Regenerate: The process of growth and renewal that allows cells, organs, and organisms to be resilient to damaging events. For example, a sea star is capable of regenerating an arm that has been damaged by a predator.

Replacement: One of the 3 Rs of animal research proposed by Russell and Burch. Replacement means replacing conscious, living vertebrates with cell or tissue cultures, computer models, and/or less developed animal species.

Sequenced Genome: A laboratory process that results in the cataloging of an organism's entire genetic information, encoded in either DNA or RNA (for many viruses).

Spinal Cord Injury: An injury to the spinal cord as a result of trauma (not disease). An example of the result of a spinal cord injury is quadriplegia.

Toxicity: The degree to which a substance can cause damage to an organism. A toxic substance is one that may be damaging or poisonous.

Transgenic Organism: A living organism in which genes, or gene regulatory regions, have been added, removed, or modified. The change in DNA will cause the organism to exhibit a new property (immune system change, genetic disorder, etc.) which can be passed to its offspring.

Type II Diabetes: One of the three types of diabetes. Also called Diabetes Mellitus Type II or Adult-onset Diabetes. The disease is characterized by high blood glucose levels due to insulin resistance and insulin deficiency.

Virus: A tiny organism that can transmit infections and disease, such as influenza and HIV.

RESOURCES

Understanding Animal Research
http://www.understandinganimalresearch.org.uk/homepage

Animal Research.info
http://www.animalresearch.info/en/home

"Models in Science Education: Application of Models in Learning and Teaching Science." Funda Omek. International Journal of Environmental & Science Education, 2008, 3 (2), 35-45. http://www.ijese.com/V3_N2_Ornek.pdf

STUDENT HANDOUT 2.1

Research Model Cards Summary Table

Name_____ Date_____ Period_____

First, sort your Research Model Cards from lower organisms to higher organisms. Then, provide a summary of the information on each card in the table below by marking an "x" in the column(s) the best represent the use of that model. Please note that the uses listed on each model card are not comprehensive. Be sure to record the reactions of your group members' to the use of this model in scientific research.

Level of Complexity	Name of Research Model	Cell biology/function	Toxicity	Drug and product development/safety	Behavioral	Embryonic development	Transplantation/prosthetic	Brain/nervous system	Heart/cardiovascular	Respiratory system	Surgical technique	Gene-environment	Specific disease/disorder:	Other:
Lower organisms														
Higher organisms														

HANDOUT

Your Reaction to its Use	Name of Research Model

HANDOUT

STUDENT HANDOUT 2.2
Research Topics

Name_____ Date_____ Period_____

Your student group will be investigating one of the following five research topics. First, review the background and research questions for all five topics. Then, your teacher will provide you with detailed information about one of the topics.

ALZHEIMER'S DISEASE

Misplacing car keys. Not remembering a familiar name. Some people become more forgetful as they get older. That's a normal part of aging. ***Alzheimer's disease*** *is not.*

Alzheimer's disease affects over five million people in the U.S. and is in the top ten leading causes of death. Over time, Alzheimer's disease gradually destroys a person's memory and ability to learn and carry out daily activities such as talking, eating, and going to the bathroom. As the disease progresses, individuals may also experience changes in personality and behavior. Unfortunately, there are no cures for Alzheimer's disease and there is no way to predict how fast someone will progress through the stages of the disease.

http://www.namenda.com/sections/about-alzheimers-disease

RESEARCH GOAL:

You are a research team trying to develop a cure for Alzheimer's disease. The team knows the brain is made up of **neurons**, and these die as the disease progresses. Alzheimer's can be studied in all animals with brains.

TYPE II DIABETES

At first the symptoms seemed so harmless, they were easy to ignore. The thirst, frequent trips to the bathroom, feeling tired and irritable all the time. Is blurred vision normal? Could this be serious for a teenager?

Diabetes affects over 23 million children and adults in the U.S. and is among the top ten causes of death. People with diabetes have high ***blood glucose*** *levels because their body no longer produces enough insulin (Type I) or their cells ignore the insulin that is produced (Type II). Glucose is a basic fuel used by cells in the body; insulin takes glucose from the blood into the cells where it can be used.*

http://www.diabetes.org

RESEARCH GOAL:

Your research team wants to better understand why some teens develop **Type II Diabetes**. In the future this knowledge could lead to drugs that reduce the risk in young adults. Insulin and **insulin receptors** have been found in all animals including worms.

HANDOUT

MALE PATTERN BALDNESS

"At the age of eighteen, I noticed an abundance of short dark hairs at my hairline and didn't know what to make of it. Then, not too long after that I noticed the crown receding and the temples cutting back sharply. Then the sickening realization that the hair on the entire top of my head was getting thinner…and all I could think about was my hair."

***Male pattern baldness** is a common, **hereditary condition** that affects roughly 40 million men in the U.S. and accounts for about 90% of all hair loss cases in men. Hair loss can affect self-esteem and standing within society, and many men are willing to buy expensive products that might prevent or decrease hair loss. About 25% of men who have male pattern baldness begin losing their hair before the age of 21.*

David M. Hatch,
http://www.malepatternbaldness.net/
http://www.WebMD.com

RESEARCH GOAL:

You and your research team are working on the production of a new drug for male pattern baldness.

ANTIBACTERIAL SOAP

*Antibacterial soap has become tremendously popular over the last number of years as a way of killing **bacteria** and **microbes** when used with water in a traditional hand washing manner. Antibacterial soaps are not the same thing as hand sanitizers, which use alcohol to kill bacteria when water may not be available. Most antibacterial soaps use the chemical Triclosan as the antibacterial agent. Antibacterial soap cannot kill **viruses**, and the chemicals do not distinguish between helpful and harmful bacteria when killing them on skin. Some concerns exist about the effects of Triclosan in the environment, and the potential rise of Triclosan-resistant bacteria that become very difficult to kill.*

RESEARCH GOAL:

Your research team has found a new antibacterial agent to replace Triclosan, and wants to use it in a new soap. If the soap can effectively kill the bacteria and viruses that cause disease without causing side effects, the researcher could prevent illness in a large population.

SPINAL CORD INJURIES

"Four days before heading back to school for the fall term a very close friend, Ray, had invited me to the Allegheny River for a canoe trip. We paddled down the river a few miles and someone had set up a rope swing. Ray grabbed the rope, climbed to the top, and swung away. As soon as the rope retreated back to the bank, I threw it up behind the platform, climbed to the top, and kicked off. It was an incredible rush. Ray went up another time and launched himself way out in the water. I had noticed another canoe coming down the river. As cool as it was to be doing what we were doing, it's always better to be showing off while doing it! I gripped the rope tight and kicked my legs straight out and gained a lot of air fast. Tucking my knees up in my chest to spin into a few flips, something wasn't right. I lost my bearings and landed head first. That's the last I remembered."

-Mark with a 6th cervical vertebra (C6) complete compression fracture causing **quadriplegia**,
http://www.dreamblvr.com/history.htm

RESEARCH GOAL:

A researcher is working to identify better methods to treat **spinal cord injuries**. Up to 12,000 people annually suffer from spinal cord injury. Treatments for spinal cord injury are limited and often do not restore lost function. Spinal cord injury models can be developed in any animal model with a spine.

HANDOUT

STUDENT HANDOUT 2.3

Alzheimer's Disease

Name_____ Date_____ Period_____

Misplacing car keys. Not remembering a familiar name. Some people become more forgetful as they get older. That's a normal part of aging. Alzheimer's disease is not.

Alzheimer's disease affects over five million people in the U.S. and is in the top ten leading causes of death. Over time, Alzheimer's disease gradually destroys a person's memory and ability to learn and carry out daily activities such as talking, eating, and going to the bathroom. As the disease progresses, individuals may also experience changes in personality and behavior. Unfortunately, there are no cures for Alzheimer's disease and there is no way to predict how fast someone will progress through the stages of the disease.

http://www.namenda.com/sections/about-alzheimers-disease

RESEARCH GOAL:

You are a research team trying to develop a cure for **Alzheimer's disease**. The team knows the brain is made up of neurons, and these die as the disease progresses. Alzheimer's can be studied in all animals with brains. To begin:

- Put aside any of the Research Model Cards that will not be useful in answering the questions.
- Put the remaining cards in order from lowest organism or model to highest organism or model (some cards might be at the same level).
- Using the Research Model Cards, answer the following questions with your group:

Alzheimer's Disease: A form of dementia, or loss of brain function, that gradually worsens over time and affects behavior, thinking, and memory.

Neuron: Also called a nerve cell, a neuron is a specialized cell in the nervous system (brain, spinal cord, and nerves) that processes and communicates information through electrical and chemical signals.

Research Questions:

1. Which models would you use to determine how **neurons** communicate with each other?

2. Which models would you use to determine how drugs change the effects of Alzheimer's on neurons?

3. Which models are particularly well-suited to the study of Alzheimer's disease in a whole organism? (i.e. disease models of that animal exist, or that organism naturally develops the disease.)

As you discuss the answers, consider:

- The benefits and limitations of each subject on the cards.
- How best to replace, reduce, and refine so the optimal number of organisms is used with the most humane methods.
- The ethical issues involved in your choices for research subjects.

HANDOUT

HANDOUT

STUDENT HANDOUT 2.4
Type II Diabetes

Name_____ Date_____ Period_____

At first the symptoms seemed so harmless, they were easy to ignore. The thirst, frequent trips to the bathroom, feeling tired and irritable all the time. Is blurred vision normal? Could this be serious for a teenager?

Diabetes affects over 23 million children and adults in the U.S. and is among the top 10 causes of death. People with diabetes have high ***blood glucose*** *levels because their body no longer produces enough* ***insulin*** *(Type I) or their cells ignore the insulin that is produced (Type II). Glucose is a basic fuel used by cells in the body; insulin takes glucose from the blood into the cells where it can be used.*

http://www.diabetes.org

RESEARCH GOAL:

Your research team wants to better understand why some teens develop **Type II Diabetes**. In the future this knowledge could lead to treatments that reduce the risk in young adults. Insulin and **insulin receptors** have been found in all animals including worms. To begin:

- Put aside any of the Research Model Cards that will not be useful in answering the questions.
- Put the remaining cards in order from lowest organism or model to highest organism or model (some cards might be at the same level).
- Using the Research Model Cards, answer the following questions with your group:

Blood Glucose: Also called blood sugar, glucose is a simple sugar that is the basic fuel used by cells in the body. The blood glucose level is a measurement of glucose in blood.

Insulin Receptors: A receptor in the body that is activated by the presence of insulin, which causes uptake of glucose.

Type II Diabetes: One of the three types of diabetes. Also called Diabetes Mellitus Type II or Adult-onset Diabetes. The disease is characterized by high blood glucose levels due to insulin resistance and insulin deficiency.

Research Questions:

1. Which models would you use to determine how cells with insulin receptors are affected by changes in insulin levels?

2. Which models would you use to determine if there are genetic factors that can influence the development of Type II Diabetes?

3. Which models could be studied to determine how diets or environmental factors contribute to the probability of getting the disease?

As you discuss the answers, consider:

- The benefits and limitations of each subject on the cards.
- How best to replace, reduce, and refine so the optimal number of organisms are used with the most humane methods.
- The ethical issues involved in your choices for research subjects.

HANDOUT

HANDOUT

STUDENT HANDOUT 2.5

Male Pattern Baldness

Name_____ Date_____ Period_____

"At the age of eighteen, I noticed an abundance of short dark hairs at my hairline and didn't know what to make of it. Then, not too long after that I noticed the crown receding and the temples cutting back sharply. Then the sickening realization that the hair on the entire top of my head was getting thinner…and all I could think about was my hair."

David M. Hatch, http://www.malepatternbaldness.net/

Male pattern baldness *is a common,* ***hereditary condition*** *that affects roughly 40 million men in the U.S. and accounts for about 90% of all hair loss cases in men. Hair loss can affect self-esteem and standing within society, and many men are willing to buy expensive products that might prevent or decrease hair loss. About 25% of men who have male pattern baldness begin losing their hair before the age of 21.*

http://www.WebMD.com

RESEARCH GOAL:

You and your research team are working on the production of a new drug for male pattern baldness. To begin:

- Put aside any of the Research Model Cards that will not be useful in answering the questions.
- Put the remaining cards in order from lowest organism or model to highest organism or model (some cards might be at the same level).
- Using the Research Model Cards, answer the following questions with your group:

Research Questions:

1. Which models would you use to determine how hair-producing cells communicate with each other?

2. Which models would you use to determine if the identified drugs have effects on any other cells in the animal?

3. Which models would you use to determine if **hair transplants** work?

As you discuss the answers consider:

- The benefits and limitations of each subject on the cards.
- How best to replace, reduce, and refine so the optimal number of organisms are used with the most humane methods.
- The ethical issues involved in your choices for research subjects.

HANDOUT

Hair Transplant: A surgical treatment for male pattern baldness that involves taking hair follicles from a donor part of the body and transplanting it into a recipient part of the body (usually the scalp). The donor site is chosen based on the hair follicles' genetic resistance to balding.

Hereditary Condition: Also called a genetic disorder, a hereditary condition is a condition or illness caused by abnormalities in genes or chromosomes. The genetic defect can be inherited from an individual's parents and/or passed down to his or her children.

Male Pattern Baldness: A genetic condition that causes hair loss in a predictable pattern along the temples and crown of the head.

HANDOUT

STUDENT HANDOUT 2.6
Antibacterial Soap

Name_____ Date_____ Period_____

*Antibacterial soap has become tremendously popular over the last number of years as a way of killing **bacteria** and **microbes** when used with water in a traditional hand washing manner. Antibacterial soaps are not the same thing as hand sanitizers, which use alcohol to kill bacteria when water may not be available. Most antibacterial soaps use the chemical Triclosan as the antibacterial agent. Antibacterial soap cannot kill **viruses**, and the chemicals do not distinguish between helpful and harmful bacteria when killing them on skin. Some concerns exist about the effects of Triclosan in the environment, and the potential rise of Triclosan-resistant bacteria that become very difficult to kill.*

RESEARCH GOAL:

Your research team has found a new antibacterial agent to replace Triclosan, and wants to use it in a new soap. If the soap can effectively kill the bacteria and viruses that cause disease without causing side effects, the researcher could prevent illness in a large population. To begin:

- Put aside any of the Research Model Cards that will not be useful in answering the questions.
- Put the remaining cards in order from lowest organism or model to highest organism or model (some cards might be at the same level).
- Using the Research Model Cards, answer the following questions with your group:

Bacteria: Tiny, single-celled organisms. These prokaryote organisms lack a nucleus and organelles within the membrane of the cell. Bacteria can form an association with other organisms that cause them to become pathogens, which can cause human disease and death from infections such as cholera, diphtheria, tuberculosis, and tetanus.

Microbe: Also called a microorganism, a microbe is one of a group of microscopic organisms that includes bacteria, fungi, archaea, protists, green algae, plankton, and planaria.

Virus: A tiny organism that can transmit infections and disease, such as influenza and HIV.

Research Questions:

1. Which models would you use to determine what agents can kill bacteria?

2. Which models would you use to determine if applying the chemical onto the skin in the form of a soap has any effects on skin?

3. Which models would you use to determine if overuse or misuse of your product can lead to antibiotic-resistant bacteria over time?

As you discuss the answers, consider:

- The benefits and limitations of each subject on the cards.
- How best to replace, reduce, and refine so the optimal number of organisms are used with the most humane methods.
- The ethical issues involved in your choices for research subjects.

HANDOUT

HANDOUT

STUDENT HANDOUT 2.7
Spinal Cord Injury

Name_____ Date_____ Period_____

"Four days before heading back to school for the fall term a very close friend, Ray, had invited me to the Allegheny River for a canoe trip. We paddled down the river a few miles and someone had set up a rope swing. Ray grabbed the rope, climbed to the top, and swung away. As soon as the rope retreated back to the bank, I threw it up behind the platform, climbed to the top, and kicked off. It was an incredible rush. Ray went up another time and launched himself way out in the water. I had noticed another canoe coming down the river. As cool as it was to be doing what we were doing, it's always better to be showing off while doing it! I gripped the rope tight and kicked my legs straight out and gained a lot of air fast. Tucking my knees up in my chest to spin into a few flips, something wasn't right. I lost my bearings and landed head first. That's the last I remembered."

*-Mark with a 6th cervical vertebra (C6) complete compression fracture causing **quadriplegia**,* http://www.dreamblvr.com/history.htm

Anti-inflammatory Drugs: Drugs used to treat inflammation. These drugs counteract the reactions caused by damaged cells, which release chemicals that stimulate the immune system, leading to swelling, and increase flow of cells to the damaged site.

Neuron: Also called a nerve cell, a neuron is a specialized cell in the nervous system (brain, spinal cord, and nerves) that processes and communicates information through electrical and chemical signals.

Quadriplegia: The result of a paralyzing injury that causes partial or total loss of the use of arms, legs, and torso, as well as the loss of sensory functions in these areas.

Regenerate: The process of growth and renewal that allows cells, organs, and organisms to be resilient to damaging events. For example, a sea star is capable of regenerating an arm that has been damaged by a predator.

Spinal Cord Injury: An injury to the spinal cord as a result of trauma (not disease). An example of the result of a spinal cord injury is quadriplegia.

RESEARCH GOAL:

A researcher is working to identify better methods to treat spinal cord injuries. Up to 12,000 people annually suffer from **spinal cord injury**. Treatments for spinal cord injury are limited and often do not restore lost function. Spinal cord injury models can be developed in any animal model with a spine. To begin:

- Put aside any of the Research Model Cards that will not be useful in answering the questions.
- Put the remaining cards in order from lowest organism or model to highest organism or model (some cards might be at the same level).
- Using the Research Model Cards, answer the following questions with your group:

Research Questions:

1. Which models would you use to determine how **neurons** communicate with each other?

2. Which models would you use to determine the effects of **anti-inflammatory drugs** administered immediately after the injury?

3. Which models would you use to determine if human patients could **regenerate** nerves after a spinal cord injury?

As you discuss the answers, consider:

- The benefits and limitations of each subject on the cards.
- How best to replace, reduce, and refine so the optimal number of organisms are used with the most humane methods.
- The ethical issues involved in your choices for research subjects.

HANDOUT

HANDOUT

TEACHER RESOURCE 2.1

Answer Key for Research Model Summary Table

Use this Answer Key to assess student performance on Student Handout 2.1—*Research Model Cards Summary Table*. This summary table is a tool to help students prepare for answering the Research Questions (as provided on Student Handout 2.2—*Research Topics*. NOTE: This chart does not reflect the comprehensive use of each model. It contains only the uses listed on the Research Model Cards.

Level of Complexity	Name of Research Model	Cell biology/function	Toxicity	Drug and product development/safety	Behavioral	Embryonic development	Transplantation/prosthetic	Brain/nervous system	Heart/cardiovascular	Respiratory system	Surgical technique	Gene-environment	Specific disesase/disorder:	Other:
This provides the "simplest" choice	Computer-based Modeling			X										
Simple	Cell Culture Systems	X	X					X	X			X		
"Lower organisms" Prokaryotes Single celled	Bacteria	X	X	X										Viral infection
Eukaryotes Single celled	Yeast	X		X										Viral infection
	Plants			X								X	Plant pathogens	Transgenic
	Worms	X						X						
	Fruit Flies			X		X							Alzheimer's	Genetic
	Zebrafish					X			X			X	Alzheimer's, diabetes	Regeneration
	Frogs	X				X								
	Chickens		X			X		X				X		
These rodents are on a similar order	Mice		X	X	X		X		X		X	X	Spinal injury, stroke, diabetes, autoimmune, cancer, bone, psychiatric	
	Rabbits			X			X			X			Asthma, Cystic fibrosis	Antibody production, respiratory system

RESOURCE

Level of Complexity	Name of Research Model	Cell biology/function	Toxicity	Drug and product development/safety	Behavioral	Embryonic development	Transplantation/prosthetic	Brain/nervous system	Heart/cardiovascular	Respiratory system	Surgical technique	Gene-environment	Specific disease/disorder:	Other:
Pigs and dogs are on a similar order	Pigs		X				X	X			X		Alzheimer's	
	Dogs				X		X		X		X			
	Macaques			X	X			X			X		HIV	Vaccine and infectious diseases
"Higher" organism	Humans			X										

YOUR REACTION TO ITS USE

Students may want to acknowledge a unique understanding or familiarity with different animals in the model card set. For example, a student who has had frogs as pets may react differently than a student without much experience with frogs. Generally, student reactions will change based on the complexity of an organism as well as that student's familiarity with an organism.

If a student states that a certain animal or group of animals should not be used in research under any circumstances, ask the student to address how ***not*** using this animal would impact research. It may also be helpful to ask, "What laws or regulations should be in place for this animal to be considered as a research subject?"

Try not to engage in debate at this point of the curriculum. The following lessons in this unit will help students better support their reasoning and justification for their answers.

Further points for consideration include:

- Many research studies investigating ***how cells work*** can be answered using cell and tissue cultures. For example, neurons and cells of the pancreas can be grown in culture. Preliminary research may not require a whole organism system.
- Many ***toxicity*** and/or ***drug studies*** can be started in cell and tissue cultures. Additional studies would eventually require whole animals. All drugs on the market must be tested on humans, too.
- Studies involving ***genetics*** would likely use a model organism that reproduces quickly and has genes that can be manipulated on the molecular level. Zebrafish are becoming the model of choice for this type of research.
- Research involving ***side effects*** of drugs or how a treatment affects a system require a whole animal system in order to see interactions between parts of the system.

RESOURCE

TEACHER RESOURCE 2.2

Questions for Use with Research Model Cards

These questions can be used to introduce students to the types and uses of organisms on the Research Model Cards through a team game. The teacher should pose a question (but not the included hint) and allow teams time to decide on an answer and write it down. The teacher then checks written answers and awards a point to each team with a correct answer. If no team gives the correct answer, the teacher may read the included hint and allow teams to try again. Encourage thoughtful guesses, since this will most likely be new information for students.

1. **Which organism has been engineered to have a clear skin, allowing scientists to more easily study the progress of cancer and the aging of internal organs? Hint: it is an amphibian.**

   Frog.

2. **Which organism has helped scientists identify genes responsible for the development of tumors that grow in the brain, lung, kidney, skin, and other organs? Hint: most of these have red eyes and are about 1/8" in length.**

   Fruit fly.

3. **Which organism played an essential role in the creation of cardiac pacemakers, heart transplant surgery and the canine distemper vaccine, helping save the lives of millions of human beings and animals? Hint: the canine distemper vaccine benefits its own kind.**

   Dog.

4. **Which small budding organism has led to the understanding of basic cellular processes, such as respiration and cell division? Hint: it is also important in the beer, bread, wine and pharmaceutical industries.**

   Yeast.

5. **Which organism helped scientists identify how to prolong the storage of donated blood, making blood transfusions a widely available life-saving procedure?**

   Rabbit.

6. **Which small mammal was responsible for the development of penicillin, an antibiotic used to treat infections? Today penicillin is the most widely used antibiotic, saving thousands of lives every day. Hint: it is the most widely used animal model.**

   Mouse.

7. **This organism has been a classical model for genetic studies for decades. It is also used extensively in pharmaceutical production. Hint: it is the major cash crop in the United States.**

   Corn.

8. **Which organism has transparent embryos, giving scientists a clear window to study genetically related diseases and the effects medical treatments have on development? Hint: this is quickly becoming one of the most-used model organisms.**

   Zebrafish.

9. **Which organism's heart valves have been used to replace damaged heart valves in human beings? Hint: the physical structure of their organs is very similar to that of human beings.**

   Pig.

10. **Which organisms have had their genomes sequenced?**

    All of them. Most are completely sequenced, and a few are still in the post-sequencing assembly stage.

Questions courtesy of *Americans for Medical Progress*, http://www.amprogress.org.

RESOURCE

TEACHER RESOURCE 2.3

Possible Answers for Research Questions

Each of the three questions on Student Handouts 2.3 – 2.7 generally corresponds to a different point in the research process. ***Note:*** A number of research models could be used to answer each question.

- ***Question #1*** focuses on ***basic research***, such as learning how cells work together and communicate. These questions can often be answered using cell or tissue cultures and may not require a whole organism system.
- ***Question #2*** focuses on ***toxicity*** and/or ***drug studies***. These represent an increased level of complexity allowing for interactions between cell types within a system. Though drug/toxicity studies may be started in cell and tissue cultures, they eventually require a living organism, usually the lowest practical model to start. Successful studies on lower organisms may lead to studies in higher model organisms. The FDA requires toxicity testing on two animal species before human trials can begin. All drugs intended for human use must be tested on humans before reaching the market.

  Question #2 may also involve studies of ***genetics***. This would likely use a model organism that reproduces quickly and has genes that can be manipulated on the molecular level. Zebrafish are becoming the model of choice for this type of research.
- ***Question #3*** looks at issues that involve animal models purpose-bred to model the disease, populations or environmental factors. Information from these types of research questions *may* have a clinical application to humans. Consenting humans are also often part of these types of studies.

ALZHEIMER'S DISEASE

1. Cell culture systems (animal models including worms and fruit flies would also work, but would be more difficult to study).
2. Mice are the most likely, but all animal models will work. Animals with a short lifespan can be advantageous for this research. Mice and rats live about two and a half years.
3. Fruit flies, zebrafish, pigs.

TYPE II DIABETES

1. Cell culture systems (animal models would also work, but would be more difficult to study).
2. Zebrafish and mice (possibly humans if there are families that have a higher incidence).
3. All animal models including humans.

MALE PATTERN BALDNESS

1. Cell culture systems (animal models would also work but would be more difficult to study).
2. Mice. Possibly rabbits, dogs, or pigs. Macaques and humans are unlikely.
3. Mice and rabbits (as well as other mammalian models).

ANTIBACTERIAL SOAP

1. Bacteria.
2. Cell culture systems (skin models exist for penetration and irritation). Mice and rabbits, as well as other mammalian models.
3. Bacteria cultures, as well as public health studies in humans.

SPINAL CORD INJURIES

1. Cell culture systems, vertebrate models.
2. Cell culture systems to study inflammation due to immunce cell response. Mice (as well as other mammalian models).
3. Zebrafish and mice (and other mammalian models), or recently-injured consenting humans.

RESOURCE

TEACHER RESOURCE 2.4
Master Copy for Research Model Cards

Copy these pages back-to-back and then cut out each card. Each student group will need one complete set of cards.

Computer-Based Modeling

Uses: For predicting the best dosage (a prescribed amount of a drug), potential toxicity (from damaging and poisonous substances), and side effects from drugs.

Advantages: No animals needed; can be used to refine animal studies.

Disadvantages: Only able to make predictions which must then be tested on animals.

Ethical Considerations: Animal studies are still needed to validate results (to be sure that the results of the modeling are accurate).

Cell Culture Systems

Uses: For basic cell biology research to determine how cells work and respond to changes in their environment. Used to measure toxic (damaging or poisonous) effects on specific cell types and to encourage cell growth and specialization. Cell culture lines exist for prostate and breast cancers, neural tissue, heart tissue, bone marrow, skin and many other cell types.

Advantages: Can be strictly controlled. Cells are easy to work with and provide results quickly.

Disadvantages: Cells are grown in artificial environments (grown in culture, such as a Petri dish, instead of inside an organism). Cells maintained for a long time in culture are different than those growing naturally inside an organism.

Ethical Considerations: Cells must be obtained from animals or humans.

Humans

Homo sapiens (animal, mammal)

Uses: For studying the safety and effectiveness of drugs and other treatments that are at the final stages of development (before they are allowed to be manufactured and sold).

Advantages: Results are strongest, since the testing is done on actual humans.

Disadvantages: Low participation by human volunteers. Costly and takes time. Ethical considerations limit most studies.

Ethical Considerations: Researchers must obtain informed consent from volunteers (volunteer must be capable of understanding the facts and risks of the study). Researchers must protect vulnerable populations (such as children, pregnant women, prisoners, and others). The study must maximize benefits and reduce harm for the volunteers.

Macaques

Macaca mulatta (animal, mammal, non-human primate)

Uses: For behavioral studies, brain function and development studies, surgical development, vaccine and infectious disease studies, and drug safety studies. HIV research relies on primates such as macaques.

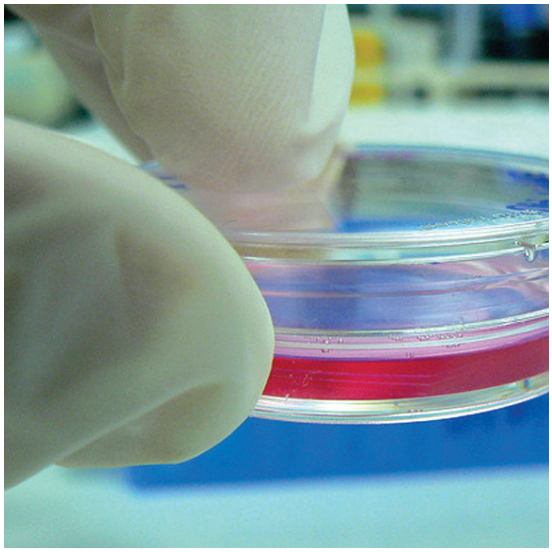
Advantages: Primates are humans' closest relatives. They provide a strong model for both behavioral (study of behavior) and physiological (study of organisms, organs, and cells) studies.

Disadvantages: Primates are expensive to house and feed, slow to breed, useful only for a limited number of studies, and genetically diverse.

Ethical Considerations: Because of their intelligence and social nature, macques require intensive care and social interaction to maintain their health.

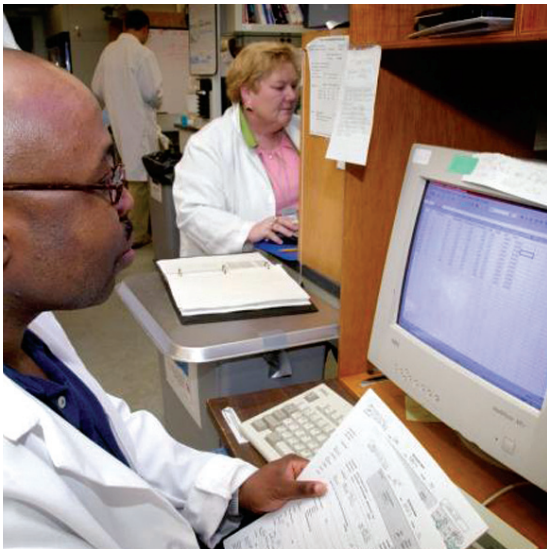
RESOURCE

Cell Culture Systems



Credit: Wikimedia, 2008. Umberto Salvagnin, http://www.flickr.com/photos/kaibara/3075268200/.

Computer-Based Modeling



Credit: Centers for Disease Control and Prevention/James Gathany, 2003.

Macaques

Macaca mulatta (animal, mammal, non-human primate)

Credit: Copyright 2007 Understanding Animal Research.

Humans

Homo sapiens (animal, mammal)

Credit: Centers for Disease Control and Prevention/James Gathany, 2006.

RESOURCE

Pigs

Sus scrofa (animal, mammal)

Uses: For transplantation, cardiac, skin and prosthetic device studies, surgical technique studies, gene-environment interaction studies, and studies of brain disorders like Alzheimer's disease.

Advantages: Mammals. Pigs have large organ systems that are similar to humans.

Disadvantages: Pigs are large, expensive to house and feed, and genetically diverse.

Ethical Considerations: Because of their intelligence and social nature, pigs require some social interaction to keep them healthy.

Dogs

Canis lupus familiaris (animal, mammal)

Uses: For behavioral studies and the development of surgical techniques for both veterinary and human applications. Dogs are also important for heart research, as well as transplantation and prosthetic device studies.

Advantages: Mammals. Dogs have large organ systems that are similar to humans. They are able to interact with researchers. Research on dogs benefits veterinary practice as well as humans.

Disadvantages: Dogs are expensive to house and feed as compared to smaller mammals.

Ethical Considerations: Because of their intelligence and social nature, dogs require some social interaction to keep them healthy. Historically, there has been public concern about the use of dogs in research.

Rabbits

Oryctolagus cuniculus (animal, mammal)

Uses: For antibody (an immune system protein) production studies, product safety testing, gene-environment interaction studies, transplantation and prosthetic device studies, surgical technique studies, and studies of respiratory diseases such as asthma and cystic fibrosis.

Advantages: Small mammals. Easy to breed and inexpensive to house and feed. Can be bred specifically for research to obtain genetically similar animals.

Disadvantages: Rabbits are larger and more expensive to house and feed than mice or rats.

Ethical Considerations: Historically, there has been public concern about the use of rabbits in research, especially the use of the Draize test on rabbits. In this test for cosmetics safety, substances are applied to the eyes or skin of conscious rabbits.

Mice

Mus musculus (animal, mammal)

Uses: For surgical technique studies, transplantation studies, drug safety studies, toxicity studies, behavioral studies, gene-environment interaction studies, and the study of diseases and disorders, including: cardiovascular disease, psychiatric disorders (mental illness), spinal injuries, stroke, diabetes, autoimmune disorders, Alzheimer's disease, cancer, bone healing, and many more.

Advantages: Small mammals. Easy to breed and inexpensive to house and feed. 80% of human genes are the same as in mice, allowing for the study of human genetic disorders and diseases. Genes can be added or removed in embryos to produce transgenic mice (where a gene has been added into a living organism) with genes that are similiar to human disorders. Currently, most animal research is conducted on mice and rats.

Disadvantages: Mice are different from humans, so not all results transfer directly to human responses.

Ethical Considerations: The creation of transgenic mice is controversial and might ultimately increase the number of animals used in research because many mice must be bred in order to produce a few with the genes of interest.

Dogs

Canis lupus familiaris (animal, mammal)

Credit: Copyright 2007 Understanding Animal Research.

Pigs

Sus scrofa (animal, mammal)

Credit: Copyright 2000 Understanding Animal Research/Wellcome Images.

Mice

Mus musculus (animal, mammal)

Credit: Copyright 2007 Understanding Animal Research.

Rabbits

Oryctolagus cuniculus (animal, mammal)

Credit: Copyright 2000 Understanding Animal Research/Wellcome Images.

Zebrafish

Danio rerio (animal, fish)

Uses: For regeneration studies (processes of renewal and growth of cells and organs), the study of embryonic development and gene-environment interaction studies. Also used for research on developmental defects in adult diseases and age-related abnormalities, such as cardiovascular disease, Alzeheimer's disease, and diabetes.

Advantages: Vertebrates. Easy and inexpensive to maintain and breed. Sequenced genome. Some transgenic zebrafish (where a gene has been added into a living organism) are available. Embryos (fertilized eggs) are transparent and develop outside of the parent's body, allowing for observation of the developing embryo.

Disadvantages: Zebrafish have many differences from humans, including many organ systems. Any drug studies on zebrafish need additional testing on mammals before human use.

Ethical Considerations: The creation of transgenic zebrafish is controversial.

Chickens

Gallus gallus (animal, bird)

Uses: For embryonic development studies (after an egg is fertilized). In particular, this includes craniofacial development studies (face and skull development), brain development studies, environmental factors studies, and toxicity (damaging or poisonous substances) studies.

Advantages: Vertebrates. Warm blooded. Easy and inexpensive to maintain and breed. Embryos (fertilized eggs) develop outside of the parent's body, allowing for observation of the developing embryo.

Disadvantages: Chickens have many differences from humans. Any drug studied on chickens needs additional testing on mammals before human use.

Ethical Considerations: The creation of transgenic chickens (where a gene has been added into a living organism) is controversial.

Frogs

Xenopus tropicalis (animal, amphibian)

Uses: For embryonic development studies (after an egg is fertilized). In cell biology and biochemistry studies, frogs are used for studying chromosome replication, control of the cell cycle, and various signaling pathways between cells.

Advantages: Vertebrates. Easy and inexpensive to maintain and breed. Large, transparent embryos (fertilized eggs) develop outside of the parent's body, allowing for observation of the developing embryo. Organ systems are complex. Genetic material can be easily manipulated to produce genetically similar organisms.

Disadvantages: The frog life cycle is very different from that of mammals.

Ethical Considerations: The creation of transgenic frogs (where a gene has been added into a living organism) is controversial. Ethical issues with frogs may differ from those with "higher" organisms like mammals.

Fruit Flies

Drosophila melanogaster (animal, insect)

Uses: Essential for research of genetics, developmental biology, and drug development. Also used for research on the effects of drugs on the progression of Alzheimer's disease. Although flies have very simple brains, they have highly developed muscles and nerves.

Advantages: Easy and inexpensive to maintain and breed. Easy to observe embryonic development (fertilized eggs). Large chromosomes. Can easily produce mutants.

Disadvantages: Invertebrates. Flies are very different from humans. Any drug studied on flies needs additional testing on mammals before human use.

Ethical Considerations: Ethical issues with flies may differ from those with "higher" organisms like mammals.

Chickens

Gallus gallus (animal, bird)

Credit: Copyright 2007 Understanding Animal Research.

Zebrafish

Danio rerio (animal, fish)

Credit: Wikimedia, 2007.
http://commons.wikimedia.org/wiki/File:Danio_rerio_port.jpg.

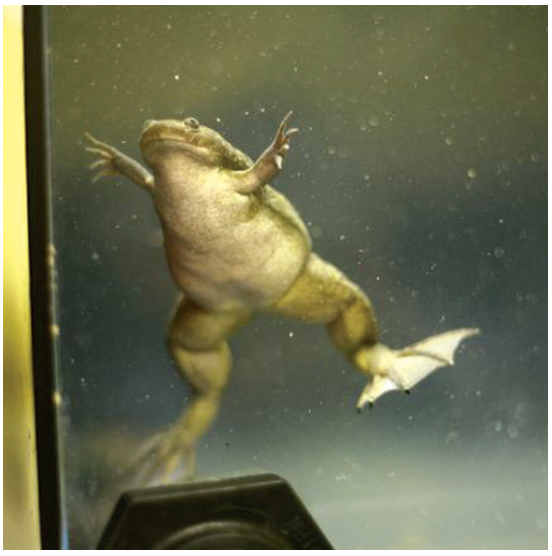
Fruit Flies

Drosophila melanogaster (animal, insect)

Credit: Wikimedia, Mr. Checker, 2009.
http://commons.wikimedia.org/wiki/File:Drosophila_melanogaster.jpg.

Frogs

Xenopus tropicalis (animal, amphibian)



Credit: Copyright 2007 Understanding Animal Research.

RESOURCE

Worms

Caenorhabditis elegans (animal, roundworm)

Uses: For research on the development of nerve cells and genetic screening. Worms are used as models of basic cellular communication.

Advantages: Instead of a brain, worms have a primitive nerve ring, making them ideal for studying the development of nerve cells. Easy and inexpensive to maintain and breed in large numbers. Sequenced genome.

Disadvantages: Invertebrates. Limited in scope. Worms are very different from humans. Any drug studied on worms needs additional testing on mammals before human use.

Ethical Considerations: Ethical issues with worms may differ from those with "higher" organisms like mammals.

Plants

Zea mays (land plant, corn)

Uses: For studies of plant diseases that affect crop production. Compounds found in plants can be used for drug development. Also used for genetic studies of transgenic organisms (where a gene has been added into a living organism), and gene-environment studies.

Advantages: Easy and inexpensive to maintain and breed. Less concern over care and welfare than animals.

Disadvantages: Plant. Require room to grow. Much of the cellular processes in plants are different than those in animals.

Ethical Considerations: Ethical issues surrounding genetic modification and the loss of genetic diversity in crop species.

Yeast

Saccaromyces cerevisiae (fungi, ascomycetes, Baker's yeast)

Uses: For studies of basic cell biology, drug development, and the effects of virus infection on cell function.

Advantages: Yeasts have similar basic cellular functions as humans. Easy to grow and maintain on a large scale.

Disadvantages: Yeasts are different from multicellular organisms.

Ethical Considerations: Less concern over care and welfare.

Bacteria

Escherichia coli (bacteria, gammaproteobacteria)

Uses: For studies of basic cell biology, drug development, and the effects of virus infection on cell function. Also used for studying how toxins (damaging or poisonous substances) affect cell growth and function.

Advantages: Bacteria can be used to synthesize medical compounds.

Disadvantages: Bacteria are very different from eukaryotic cells (cells that have a nucleus contained inside a membrane).

Ethical Considerations: Less concern over care and welfare. Much concern over the development of "super bugs" that are resistant to antibiotics.

Plants

Zea mays (land plant, corn)

Credit: Wikimedia, 2009, Ashlyak at ml.wikipedia.
http://commons.wikimedia.org/wiki/File:Corn_01.JPG.

Worms

Caenorhabditis elegans (animal, roundworm)

Credit: Centers for Disease Control and Prevention/Dr. Mae Melvin, 1974.

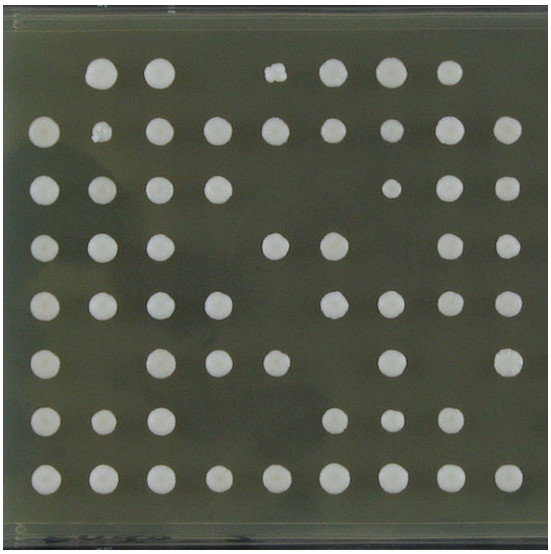
Bacteria

Escherichia coli (bacteria, gammaproteobacteria)

Credit: Centers for Disease Control and Prevention/Pete Seidel, 2010.

Yeast

Saccaromyces cerevisiae (fungi, ascomycetes, Baker's yeast)



Credit: Wikimedia, 2009, Masur.
http://commons.wikimedia.org/wiki/File:Yeast_colonies_array_96_format.jpg.

RESOURCE