Hello Students,

This resource packet includes a project that you can work on independently at home. You should also have project packets for some of the other courses you are enrolled in. Each project can be completed over multiple days, and the projects can be completed in any order. These projects are standards-aligned and designed to meet the Remote Learning instructional minutes guidelines by grade band.

High school project packets are available for the following courses:

- English 1
- Algebra
- Biology
- US History
- English 2
- Geometry
- Chemistry
- World Studies
- English 3
- Algebra 2
- Physics
- Civics
- English 4

Additional enrichment activities are also available and organized into Read, Write, Move, Design, and Solve categories to engage you in learning in many different ways while at home. Please be sure to also pick up an enrichment packet for access to these activities.

Use the table of contents on this page to navigate through the project packet.

**HS Biology Project: What does a fever do to the human body?**
HS Biology Project: What does a fever do to the human body?

<table>
<thead>
<tr>
<th>Estimated Time</th>
<th>~225 minutes of project time for each course</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade Level Standard(s)</td>
<td>HS LS 1-3. Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.</td>
</tr>
<tr>
<td>Caregiver Support Option</td>
<td>Caregivers can assist by discussing questions, models, and hypotheses with the student, as well as helping in the design of the experiment, or by participating in it.</td>
</tr>
<tr>
<td>Question to Explore</td>
<td>What does a fever do to the human body?</td>
</tr>
<tr>
<td>Student Directions</td>
<td>Students should begin the activity by coming up with their own idea for what happens in a human body when they have a fever. They will then read about endotherms and ectotherms while analyzing data and figures to begin to understand thermoregulation. They will then analyze data and conduct an experiment to determine whether humans are endotherms or ectotherms. Afterwards, they will read a longer article before returning to their initial model and explanation to revise it using their new evidence.</td>
</tr>
</tbody>
</table>

Introductory Activity: What does a fever do to the human body?


What's the temperature in the room where you're sitting right now? My guess would be that it's not exactly 98.6°F. Yet, your body temperature is usually very close to this value. In fact, if your core body temperature doesn't stay within relatively narrow limits—from about 95 °F to 107 °F—the results can be dangerous or even deadly.

The tendency to maintain a stable, relatively constant internal environment is called **homeostasis**. The body maintains homeostasis for many factors in addition to temperature. For instance, the concentration of various ions in your blood must be kept steady, along with pH and the concentration of glucose. If these values get too high or low, you can end up getting very sick. You may have learned about diabetes, an affliction which results from the body’s homeostatic systems meant to control blood sugar failing.

Homeostasis is maintained at many levels, not just the level of the whole body as it is for temperature. For instance, the stomach maintains a pH that’s different from that of surrounding organs, and each individual cell maintains ion concentrations different from those of the surrounding fluid. Maintaining homeostasis at each level is key to maintaining the body’s overall function.

Another disruption to homeostasis in the body is a fever, one of the common symptoms of COVID-19. When a child or parent becomes feverish with shivers, chills, and sweats, our first thought is to get the temperature down. Pharmacies sell billions of fever-reducing pills like aspirin and acetaminophen every year! Increasingly, medical researchers are discovering that fever has endured in mammals and other creatures for good reasons, though the reasons why are not clear. Often, a fever in
response to an infection is actually a reflection of the body’s defenses going into high gear. Some parts of the immune system work better at a higher temperature, which strengthens resistance to infection and increases the odds of survival.

The new thinking is that a mild fever can be a positive adaptation and shouldn’t necessarily be treated. At other times, though, fever may spur the microbes’ growth rate by raising the temperature of the host body. In this case, the attackers have evolved a way to chemically manipulate the host’s immune system for their own advantage. And a high fever is a danger sign, especially in young children. A fever can be an indicator of COVID-19, as well as many more severe infections, so it is often best to consult a medical professional before attempting to treat yourself.

What is this mysterious phenomenon, fever? On your own piece of paper, create a model based on the template below of what you think is happening inside the human body at various points over the course of a person experiencing and recovering from a fever.

Activity 1: Endotherms vs. Ectotherms
Adapted from https://www.biointeractive.org/classroom-resources/how-did-dinosaurs-regulate-body-temperature

This activity explores how animals can maintain homeostasis by regulating, or controlling, their body temperatures to survive in their environments. You will learn one method to determine how living animals regulate their body temperatures, and use real scientific data to investigate how different organisms regulate their body temperature.

A. Thermoregulation in Living Animals
Figure 1 (on the next page) shows four different animals. Think about the temperature inside the body of each animal compared to the temperature of the environment where that animal lives.

1. Would you expect any differences between the body temperatures of these animals and the temperatures of their environments? Is your answer the same for all the animals? Why or why not? (Write your response on a separate sheet of paper.)
To survive, most animals regulate their body temperatures to keep them within a certain range. The process of regulating body temperature is called thermoregulation. Based on how they regulate their body temperatures, most animals fit into two main categories: ectotherms or endotherms.

**Ectotherms**, sometimes called “cold-blooded,” regulate their body temperatures using heat from the outside environment. (The prefix ecto- comes from the Greek word for “outside.”) As a result, the body temperature of an ectotherm depends on the temperature of its environment. The ectotherm can adjust its body temperature by moving to different locations. For example, a lizard may move to a sunny spot to warm up or to a shady spot to cool down.

**Endotherms**, sometimes called “warm-blooded,” regulate their body temperatures using heat generated inside their bodies. (The prefix endo- comes from the Greek word for “inside.”) An endotherm uses its internal heat to keep its body temperature stable, even when temperatures in its environment are changing. Arctic foxes and polar bears, for example, can keep their internal body temperatures at about 38°C, even when the air temperature dips down to −40°C.

2. Define “ectotherm” and “endotherm” in your own words. List four new examples of animals that would fit into each category. (Write your response on a sheet of paper.)

Both ectotherms and endotherms generate some heat by breaking down food. Food is broken down by **cellular respiration** to produce cellular energy in the form of ATP. ATP is used for all types of biological “work,” such as growth, movement, and reproduction. During cellular respiration, some of the chemical energy from food is also converted into heat. The chemical reactions that occur in cells, including breaking down food molecules and generating ATP, are called **metabolism**. The rate at which animals transform chemical energy in food and release heat is the **metabolic rate**, which is measured in joules (or calories) per second.

Because endotherms use the heat generated by metabolism to regulate their body temperatures, they must generate much more heat than ectotherms do. As a result, endotherms generally have higher metabolic rates. The metabolic rate of an endotherm at rest, called the **resting metabolic rate**, tends to be 5–20 times higher than that of an ectotherm with a similar mass.

Endotherms can also generate heat by shivering. Shivering rapidly contracts the muscle fibers to use energy and produce heat. Making a lot of heat — plus having insulating fur, feathers, or clothes — keeps endotherms warm in cold environments.
3. According to a major scientific principle called the law of conservation of energy (or the second law of thermodynamics), energy cannot be created or destroyed. However, energy can be transformed. Summarize some of the energy transformations described in the paragraphs above. (Write your response on a sheet of paper.)

Since endotherms tend to have higher metabolic rates than ectotherms, they are generally more active, grow and reproduce faster, and thrive over a wide range of temperatures. However, endotherms must also eat much more often and are more likely to run out of food. A shrew (a small endotherm similar to a mouse) may starve to death in a day without food. A similarly sized lizard (an ectotherm), on the other hand, could go without food for several weeks. Amphibians and most reptiles, fish, and invertebrates are ectotherms. Mammals and birds are endotherms. What about dinosaurs?

4. Predict whether dinosaurs were more like endotherms or ectotherms. Support your prediction with evidence from the paragraphs above and your own knowledge. (Write your response on a sheet of paper.)

B. Metabolism and Mass of Living Animals - One way to determine whether animals are ectotherms or endotherms is to look at their metabolic rates. Scientists often measure resting metabolic rate, which is based on how much oxygen the animal uses while at rest at a particular temperature. This rate can be compared to the metabolic mass, the animal’s mass when its metabolic rate was measured. Table 1 shows resting metabolic rates and metabolic masses for a variety of animals living today. These data were compiled from many previous studies by evolutionary biologist John Grady and his colleagues.

<table>
<thead>
<tr>
<th>Animal</th>
<th>Type of Animal</th>
<th>Metabolic Mass (g)</th>
<th>Metabolic Rate (joules/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alligator</td>
<td>Reptile</td>
<td>1,287</td>
<td>0.67</td>
</tr>
<tr>
<td>Bear</td>
<td>Mammal</td>
<td>135,000</td>
<td>104.2</td>
</tr>
<tr>
<td>Bobcat</td>
<td>Mammal</td>
<td>9,400</td>
<td>23.58</td>
</tr>
<tr>
<td>Chimpzeen</td>
<td>Mammal</td>
<td>45,000</td>
<td>52.32</td>
</tr>
<tr>
<td>Cod</td>
<td>Fish</td>
<td>761.1</td>
<td>0.045</td>
</tr>
<tr>
<td>Dog</td>
<td>Mammal</td>
<td>38,500</td>
<td>49.02</td>
</tr>
<tr>
<td>Elephant</td>
<td>Mammal</td>
<td>3,672,000</td>
<td>2336.0</td>
</tr>
<tr>
<td>Emerald rock cod</td>
<td>Fish</td>
<td>178.1</td>
<td>0.035</td>
</tr>
<tr>
<td>Gila monster</td>
<td>Reptile</td>
<td>463.9</td>
<td>0.148</td>
</tr>
<tr>
<td>Grouse</td>
<td>Bird</td>
<td>4,010</td>
<td>11.63</td>
</tr>
<tr>
<td>Horse</td>
<td>Mammal</td>
<td>260,000</td>
<td>362.9</td>
</tr>
<tr>
<td>Kangaroo</td>
<td>Mammal</td>
<td>28,500</td>
<td>31.35</td>
</tr>
<tr>
<td>Lemon shark</td>
<td>Fish</td>
<td>1,600</td>
<td>0.959</td>
</tr>
<tr>
<td>Monitor lizard</td>
<td>Reptile</td>
<td>32.5</td>
<td>0.017</td>
</tr>
<tr>
<td>Nile crocodile</td>
<td>Reptile</td>
<td>215.3</td>
<td>0.064</td>
</tr>
<tr>
<td>Partridge</td>
<td>Bird</td>
<td>475</td>
<td>1.961</td>
</tr>
<tr>
<td>Python</td>
<td>Reptile</td>
<td>1,307</td>
<td>0.13</td>
</tr>
<tr>
<td>Rabbit</td>
<td>Mammal</td>
<td>3,004</td>
<td>6.063</td>
</tr>
<tr>
<td>Raven</td>
<td>Bird</td>
<td>1,203</td>
<td>5.514</td>
</tr>
<tr>
<td>Saltwater crocodile</td>
<td>Reptile</td>
<td>388,000</td>
<td>38.52</td>
</tr>
<tr>
<td>Sandbar shark</td>
<td>Fish</td>
<td>3,279</td>
<td>1.153</td>
</tr>
<tr>
<td>Spear-nosed bat</td>
<td>Mammal</td>
<td>84.2</td>
<td>0.559</td>
</tr>
<tr>
<td>Sperm whale</td>
<td>Mammal</td>
<td>11,380,000</td>
<td>4325.0</td>
</tr>
<tr>
<td>Tiger</td>
<td>Mammal</td>
<td>137,900</td>
<td>193.9</td>
</tr>
</tbody>
</table>

Table 1. Metabolic masses and resting metabolic rates for sample vertebrates. In some cases, the measurement was taken from a juvenile instead of a fully grown animal (for example, the alligator and Nile crocodile). Data from Grady et al. (2014).
Figure 2 is a graph of the data in Table 1. It uses logarithmic scales on both axes to show data points over a large range. On a graph with regular linear scales, it would be hard to show all these data points together, since some of the animals and their metabolic rates are tiny, while others are huge.

**Figure 2.** Metabolic rate versus metabolic mass of the vertebrates in Table 1. The filled blue diamonds represent ectotherms. The filled red circles represent endotherms. Figure adapted from Grady et al. (2014).

Use Figure 2 to answer questions 1-5. Write your response on a sheet of paper.

1. Based on the general trends in Figure 2:
   a. How do the metabolic rates of ectotherms compare with those of endotherms of similar mass?
   b. How do the metabolic rates of both ectotherms and endotherms vary with mass?
2. An average adult cheetah has a metabolic mass of 44,010 grams and a resting metabolic rate of 61.77 joules per second. Use this information to add a data point for the cheetah to Figure 2. Based on these data, would you characterize the cheetah as an ectotherm or endotherm? Support your answer with evidence from the graph.

3. Briefly describe other data you could collect to provide additional evidence for whether the cheetah is an ectotherm or an endotherm.

4. As the masses of the animals increase, how do their metabolic rates tend to change? Answer this question for both ectotherms and endotherms.

5. Make a claim about how the metabolic rates of endotherms compare with those of ectotherms of similar mass. Support your claim with at least three pairs of data points from Figure 2.

C. Estimating Dinosaur Mass and Metabolism - Part 2 showed how mass and metabolism can be used to distinguish ectotherms from endotherms. These properties could also be used to determine whether dinosaurs were more like ectotherms or endotherms. But since dinosaurs have been extinct for millions of years, we can’t measure their masses or metabolisms directly. Instead, we estimate these properties using fossilized bones.

A dinosaur’s mass can be estimated from its bone size. An animal’s mass generally increases with the size of its bones. (So a small animal, such as a mouse, usually has lighter, narrower bones than a large animal, such as an elephant, has.) We can measure the size of a dinosaur’s bones, then compare these measurements to those of living animals, to estimate how large the dinosaur was.

A dinosaur’s metabolism can be estimated based on its bone rings, which are similar to the growth rings in tree trunks. The widths of the bone rings can be used to estimate an animal’s growth rate, which is how much the animal grows per unit of time. (Each year, for example, a bone may grow a new ring. Fast-growing animals grew more during that year, so their bone ring will be bigger and wider than it would be for slow-growing animals.) Growth rate is related to metabolic rate, so we can use the growth rates estimated from bone rings to estimate an animal’s metabolic rate. These estimated metabolic rates are similar to those measured directly from oxygen use.

Use the information in this reading to answer the questions below (on a separate sheet of paper).

1. Summarize the evidence used to estimate the masses and the metabolic rates of dinosaurs.
2. Explain why a mouse (an endotherm) would probably have wider bone rings than a similarly sized lizard (an ectotherm).

Using the methods described above, Grady and colleagues estimated the masses and metabolic rates of 21 dinosaurs. Their estimates for five of these dinosaurs are shown in Table 2.

Directions: Plot the Table 2 data on Figure 2 (from Part 1 of the activity), then answer the questions below.

3. As the masses of the dinosaurs increase, how do their metabolic rates change? How does this compare to the living animals?

Table 2. Estimated masses and resting metabolic rates of five dinosaurs. Data from Grady et al. (2014).
Directions: Draw three lines of best fit ("trend lines") in Figure 2: one for the endotherms, one for the ectotherms, and one for the dinosaurs. (See Appendix 2 for example)

4. Make a claim about whether the relationship between mass and metabolic rate in dinosaurs follows a pattern more similar to that of ectotherms or endotherms. Support your answer with evidence from the graph. (Write your response on a sheet of paper.)

5. Based on the graph, which animal would you expect to have wider rings in its bones: a mountain lion or the dinosaur called a Troodon? (Troodons were about the same mass as mountain lions and looked like feathered velociraptors.) Explain your answer. (Write your response on a sheet of paper.)

Activity 2: What are Humans?

A. Data Analysis as Evidence - You may already have knowledge of or a hypothesis concerning whether humans are ectotherms, mesotherms, or endotherms, but now you're going to use multiple pieces of evidence to construct a Claim, Evidence, Reasoning argument to address that question.

Participants in a study had their mass recorded, and then their resting metabolic rate (RMR) measured. In order to measure the RMR, participants were told to refrain from exercise for 24 hours, and then hooked up a device that measures their breathing. Because every calorie a person consumes requires a fixed amount of oxygen to be converted to energy, the device can measure the oxygen you consume to calculate the amount of calories burned. This in turn gives us the RMR.

To the left is a data table containing the resting metabolic rate and mass of the participants in the study. You can use the data in combination with figure 2 in activity 1 to support your argument. Two things that are important to notice: figure 1 is a logarithmic graph, so the axes look a little different than more common linear graphs. Also, the mass data for humans is in kg, not g.

B. Designing an Experiment to Gather Evidence - If you are unable to conduct the procedure, you can use the data gathered below the experiment for use in writing your argument in part C.

As stated in activity 1, the body temperature of an ectotherm changes with its environment, while an endotherm maintains a stable body temperature by regulating it. What this means is that an ectotherm’s temperature will go up and down depending on what they’re doing and what environment they’re in, while endotherms will stay the same temperature, or very close to it (under normal conditions). You're going to conduct an experiment to see whether human body temperatures stay the same or change under varied conditions.

In order to test this question, you will first conduct a baseline procedure, which is provided in the table below. After collecting that data, pick a variable that you can change for the experiment. Possible variables to change are listed in the Independent Variables box. You may pick one of those variables to change, or you can pick one of your own that’s not on the list. Then, modify the baseline procedure so that the variable you picked is changed in the new procedure, and write it down on your own paper. It is very important to only change one variable; if you change more than one, then the results won’t be accurate. For example, if you pick the duration of exercise as the variable that you want to change, but in your second procedure you make the experiment longer while also wearing a coat, you have changed two variables at the same time, which will invalidate your experiment. Any variables that you are keeping the same in each experiment should be listed in the
Controlled Variables box. You can conduct the experiment yourself by being the participant, or you can have someone conduct the experiment while you collect the data. Create the following table on your own paper, and fill in the boxes.

<table>
<thead>
<tr>
<th>Possible Materials</th>
<th>Independent Variable</th>
<th>Dependent Variables</th>
<th>Controlled Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>You may not use all the materials</td>
<td>The variable changed by the scientist - circle one</td>
<td>The variable or variables measured by the scientist which change as a result of the independent variable</td>
<td>The variables that are kept the same between experiments</td>
</tr>
<tr>
<td>• Thermometer</td>
<td>• Duration of exercise</td>
<td>• Temperature</td>
<td></td>
</tr>
<tr>
<td>• Thermal perception scale</td>
<td>• Insulation (exercising with or without coat)</td>
<td>• Thermal perception (how hot or cold you feel)</td>
<td></td>
</tr>
<tr>
<td>• Stopwatch/timer</td>
<td>• Type of exercise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• (optional)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jacket/sweater/coat</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Experimental Question**

What are you investigating?

**Baseline Procedure**

1. Measure and record the participant’s body temperature using a thermometer.
2. Have the participant rate themselves using the thermal perception scale (shown on the left of the procedure) based on how hot or cold they currently feel.
3. Have the participant begin some form of cardio exercise (you can pick any exercise such as jogging in place, jumping jacks, burpees, etc). Start the stopwatch when the participant begins exercising.
4. After 1 minute, ask the participant to rate themselves on the thermal perception scale. If their perceived temperature has not increased, the intensity of exercise can be increased.
5. The participant should stop exercising after 2 minutes.
6. Have the participant rate themselves again on their thermal perception, and measure their body temperature again with the thermometer.
7. Record the collected data in your own table, along with any observations of the participant (are they doing anything now that they weren’t doing before the exercise?)

**Revised Procedure**

Write your revised procedure on your own paper
The data below was collected from several participants who took part in a similar experiment.

**Experiment 1:** This experiment was conducted exactly as stated in the baseline procedure.

<table>
<thead>
<tr>
<th>Experiment 1: Baseline Procedure - Thermal Perception</th>
<th>Experiment 2: 4 Minutes of Exercise - Thermal Perception</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant</td>
<td>1</td>
</tr>
<tr>
<td>Before exercise</td>
<td>Neutral</td>
</tr>
<tr>
<td>After exercise</td>
<td>Warm</td>
</tr>
</tbody>
</table>

**Experiment 1: Baseline Procedure - Body Temperature (°F)**

<table>
<thead>
<tr>
<th>Participant</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before exercise</td>
<td>98.6</td>
<td>98.6</td>
<td>98.3</td>
<td>98.6</td>
<td>98.6</td>
</tr>
<tr>
<td>After exercise</td>
<td>98.7</td>
<td>98.6</td>
<td>98.4</td>
<td>98.6</td>
<td>98.9</td>
</tr>
</tbody>
</table>

**Experiment 2: 4 Minutes of Exercise - Body Temperature (°F)**

<table>
<thead>
<tr>
<th>Participant</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before exercise</td>
<td>98.5</td>
<td>98.5</td>
<td>98.3</td>
<td>98.6</td>
<td>98.7</td>
</tr>
<tr>
<td>After exercise</td>
<td>98.6</td>
<td>98.6</td>
<td>98.5</td>
<td>98.9</td>
<td>98.7</td>
</tr>
</tbody>
</table>

**C. Formulating an Argument**

Using the data from both parts A and B of this activity, write a Claim, Evidence, Reasoning argument that answers the following question: **Are humans endotherms or ectotherms?**

On a separate piece of paper:

**Are humans endotherms or ectotherms?**

<table>
<thead>
<tr>
<th><strong>Claim</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>I think that ____ is caused by....</td>
</tr>
<tr>
<td>I believe that ____ has a role in how ____ happens.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Evidence</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>My evidence comes from...[name the type of data and the activity it came from]. I saw that...[name the particular trend, or outcome]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Reasoning</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>I think this evidence supports my claim because if these trends in data are happening, then it means that...[state a brief causal chain of events—this chain has to be consistent with known science ideas/facts].</td>
</tr>
</tbody>
</table>

**Activity 3: How do Organisms Regulate Their Body Temperature?**


**A. Reading an Article for Information**

Directions: Draw the metacognitive reading log (below) on a sheet of paper and fill it in as you read the following text. In the left column put important information from the text, and in the right column put your reactions to the pieces of information.

**Metacognitive Reading Log**

<table>
<thead>
<tr>
<th>Important Ideas and Information in the Text</th>
<th>My Thoughts, Feelings, and Questions</th>
</tr>
</thead>
</table>

Chicago Public Schools
Maintaining Homeostasis - Biological systems like those of your body are constantly being pushed away from their balance points. For instance, when you exercise, your muscles increase heat production, nudging your body temperature upward. Similarly, when you drink a glass of fruit juice, your blood glucose goes up. Homeostasis depends on the ability of your body to detect and oppose these changes.

Maintenance of homeostasis usually involves **negative feedback loops**. These loops act to oppose the stimulus, or cue, that triggers them. For example, if your body temperature is too high, a negative feedback loop will act to bring it back down towards the set point, or target value, of 98.6 °F.

How does this work? First, high temperature will be detected by sensors—primarily nerve cells with endings in your skin and brain—and relayed to a temperature-regulatory control center in your brain. The control center will process the information and activate effectors—such as the sweat glands—whose job is to oppose the stimulus by bringing body temperature down.

Any situation that throws your body’s homeostatic state off balance can trigger various chemical, physical, and even behavioral reactions in an attempt to correct back to that normal state. We will focus on the triggers and responses that relate to temperature maintenance.

**Temperature Regulation Strategies** - Why do lizards sunbathe? Why do jackrabbits have huge ears? Why do dogs pant when they’re hot? Animals have quite a few different ways to regulate body temperature! These thermoregulatory strategies let them live in different environments, including some that are pretty extreme.

Polar bears and penguins, for instance, maintain a high body temperature in their chilly homes at the poles, while kangaroo rats, iguanas, and rattlesnakes thrive in Death Valley, where summertime highs are over 100 °F(38 °C).
Mechanisms of Thermoregulation - As a refresher, animals can be divided into endotherms, mesotherms, and ectotherms based on their temperature regulation.

- **Endotherms**, such as birds and mammals, use metabolic heat to maintain a stable internal temperature, often one different from the environment.
- **Mesotherms** use a thermoregulatory strategy intermediate to cold-blooded ectotherms and warm-blooded endotherms
- **Ectotherms**, like lizards and snakes, do not use metabolic heat to maintain their body temperature but take on the temperature of the environment.

Both endotherms and ectotherms have **adaptations**—features that arose by **natural selection**—that help them maintain a healthy body temperature. These adaptations can be behavioral, **anatomical**, or **physiological**. Some adaptations increase heat production in endotherms when it’s cold. Others, in both endotherms and ectotherms, increase or decrease exchange of heat with the environment.

We will look at two broad categories of thermoregulatory mechanisms in this article:

- Increasing metabolic heat production
- Controlling the exchange of heat with the environment

**Metabolism and heat production**

It’s probably not news to you that animals (such as humans) need food as a source of energy. But why is this the case?

The molecules in your breakfast, lunch, or dinner have energy stored in their chemical bonds. Some of your body’s metabolic reactions, like the ones that make up cellular respiration, extract this energy and capture part of it as **adenosine triphosphate** (ATP). This energy-carrying molecule can, in turn, be used to power other metabolic reactions that keep your cells running.

The business of extracting energy from fuel molecules and using it to power cellular reactions is not a perfectly efficient process. In fact, no energy transfer can be perfectly efficient – that’s a basic law of physics. Instead, each time energy changes forms, some amount of it is converted into a non-usable form. In the reactions of an animal’s metabolism, much of the energy stored in fuel molecules is released as heat.

This is not necessarily a bad thing! Some animals (endotherms) can use (and regulate) their metabolic heat production to maintain a relatively constant body temperature. These endotherms include mammals, such as humans, as well as birds. Ectotherms, on the other hand, are animals that don’t use metabolic heat production to maintain a constant body temperature. Instead, their body temperature changes with the temperature of the environment. Lizards and snakes are examples of ectotherms.

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Left panel based on data from Cannon and Nedergaard, Figure 2, and on similar figure in Purves et al. Right panel based on theoretical graph from Meek Figure 1 and on Akin Fig. 1.
**Increasing heat production—thermogenesis** - Endotherms have various ways of increasing metabolic heat production, or **thermogenesis**, in response to cold environments.

One way to produce metabolic heat is through muscle contraction—for example, if you shiver uncontrollably when you’re very cold. Both deliberate movements—such as rubbing your hands together or going for a brisk walk—and shivering increase muscle activity and thus boost heat production.

**Nonshivering thermogenesis** provides another mechanism for heat production. This mechanism depends on specialized fat tissue known as **brown fat**, or brown adipose tissue. Some mammals, especially hibernators and baby animals, have lots of brown fat. Brown fat contains many mitochondria with special proteins that let them release energy from fuel molecules directly as heat instead of channeling it into formation of the energy carrier ATP.

**Controlling the loss and gain of heat** - Animals also have body structures and physiological responses that control how much heat they exchange with the environment:

- Circulatory mechanisms, such as altering blood flow patterns
- Insulation, such as fur, fat, or feathers
- Evaporative mechanisms, such as panting and sweating

**Circulatory mechanisms** - The body’s surface is the main site for heat exchange with the environment. Controlling the flow of blood to the skin is an important way to control the rate of heat loss to—or gain from—the surroundings.

**Vasoconstriction and vasodilation** - In endotherms, warm blood from the body’s core typically loses heat to the environment as it passes near the skin. Shrinking the diameter of blood vessels that supply the skin, a process known as vasoconstriction, reduces blood flow and helps retain heat.

On the other hand, when an endotherm needs to get rid of heat—say, after running hard to escape a predator—these blood vessels get wider, or dilate. This process is called vasodilation. Vasodilation increases blood flow to the skin and helps the animal lose some of its extra heat to the environment.
Evaporative mechanisms - Land animals often lose water from their skin, mouth, and nose by evaporation into the air. Evaporation removes heat and can act as a cooling mechanism. For instance, many mammals can activate mechanisms like sweating and panting to increase evaporative cooling in response to high body temperature.

- In sweating, glands in the skin release water containing various ions—the "electrolytes" we replenish with sports drinks. Only mammals sweat.
- In panting, an animal breathes rapidly and shallowly with its mouth open to increase evaporation from the surfaces of the mouth. Both mammals and birds pant, or at least use similar breathing strategies to cool down.

In some species, such as dogs, evaporative cooling from panting helps keep the brain from overheating!

B. Metacognitive Reflection on Reading

Directions: On your own piece of paper, write a reflection on how you read the article by addressing the following prompts and record the minutes you were actively engaged in reading: ____

Observations About How You Read
- Did you get distracted while reading? What did you do or what might you do to solve that problem?
- Did you get confused while reading? What did you do or what might you do to solve that problem?
- Did you lose interest while reading? What did you do or what might you do to solve that problem?
- Did you get stopped by unfamiliar words while reading? What did you do or what might you do to solve that problem?
- Did you get stopped by long (and complex) sentences or paragraphs while reading? What did you do or what might you do to solve that problem?
- Did you have a surprising experience while reading? What did you do?

Activity 4: Reflection

After gathering information from all the activities and investigations, it’s time to revise the model you made of what causes a fever, and explain what is happening inside the human body at various points over the course of a person experiencing and recovering from a fever. Now you must also include evidence you’ve gathered that supports your explanation, and describe the scientific reasoning which explains how that evidence supports your claim. Additionally, pick two aspects of your model that you revised from your initial model, and explain what evidence supports those revisions.
Draw how body systems interact in response to changing temperature

Time

Before
Fever

During
Fever

After
Fever

Explain How The Body Tries to Maintain Its Temperature

**Instructions**

Using the tool below, justify the changes to your model using the evidence we have gathered throughout our investigations in this storyline. Your Summary Table will help you consider which pieces of evidence are most appropriate to choose to justify revisions to your model.

<table>
<thead>
<tr>
<th>Feature of My Model I Am Revising</th>
<th>Revision That I Am Making to My Model</th>
<th>Evidence Supporting My Revision (include multiple pieces as needed)</th>
<th>Connection Between Evidence and Model Revision</th>
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**Chicago Public Schools**
Cross Content Connection:

- **English Language Arts Standards » Writing » Grade 9-10 - CCSS.ELA-LITERACY.W.9-10.1** - Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.

- **English Language Arts Standards » Reading: Informational Text » Grade 9-10 - CCSS.ELA-LITERACY.RI.9-10.10** - By the end of grade 9, read and comprehend literary nonfiction in the grades 9-10 text complexity band proficiently, with scaffolding as needed at the high end of the range.

- **High School: Statistics & Probability » Interpreting Categorical & Quantitative Data - CCSS.MATH.CONTENT.HSS.ID.1-3** - Summarize, represent, & interpret data on single count of measurement variable

Glossary

- **Adaptations**: a change or the process of change by which an organism or species becomes better suited to its environment.

- **Adenosine Triphosphate (ATP)**: a source of energy for chemical reactions in the cells of the body, especially muscle contractions, nerve impulses, and metabolism.

- **Anatomical**: relating to bodily structure (e.g. fingers, foot, skull, etc.).

- **Brown Fat**: a dark-colored adipose (fat) tissue with many blood vessels, involved in the rapid production of heat in hibernating animals and human babies.

- **Cellular Respiration**: a set of metabolic reactions and processes that take place in the cell to convert biochemical energy from food/nutrients into ATP and then release waste products.

- **Electrolytes**: a liquid or gel that contains ions and can be used for cellular processes and metabolism, (e.g., Na⁺ in a cell; Gatorade)

- **Homeostasis**: any self-regulating process by which biological systems tend to maintain stability while adjusting to conditions that are optimal for survival.

- **Logarithmic Scale**: a way of displaying numerical data over a very wide range of values in a compact way—typically the largest numbers in the data are hundreds or even thousands of times larger than the smallest numbers.

- **Metabolism**: the chemical processes that occur within a living organism to maintain life and support living functions.

- **Metabolic Rate**: the rate at which metabolism occurs in a living organism.

- **Microbe**: a very small living thing, especially one that causes disease, that can only be seen with a microscope.

- **Natural Selection**: the process whereby organisms better adapted to their environment tend to survive and produce more offspring.

- **Nonshivering thermogenesis**: heat production due to metabolic energy transformation by processes that do not involve contraction of skeletal muscles (i.e. shivering).

- **Physiological**: relating to the way in which a living organism or bodily part functions.

- **Resting Metabolic Rate**: the total number of calories burned when your body is completely at rest.

- **Thermoregulation**: a process that allows your body to maintain its core internal temperature.

**Best Fit Line Example:**

Sketch the line that appears to most closely follow the correlation. Don’t just choose the first and last data points, but construct a line that best represents the trend. Most likely, you are looking for the median values, and this is why sometimes the trend line is also called the median fit line.

![Best Fit Line Example](Line of Best Fit)