Robotic Zoo

USING LEGO MINDSTORMS NXT

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1. PHYSICAL ADAPTATIONS TO HABITAT

Goal: To build a model of an animal that has a physical characteristic specifically adapted to its native habitat. Students connect a feature of the animal with a feature of its habitat, and discuss why that characteristic helps the animal survive.

Main Themes:

- Construction of physical structures
- Evolution of animal adaptations for habitat conditions

Biology Theory: Animals' characteristics slowly change over time to better match their habitat. The changes that help the animal survive give that animal an advantage over others; that animal is more likely to survive and pass this trait onto the next generation of the animal. In this way, animals evolve and develop characteristics, or traits, that are specialized for their habitat.

Activity Instructions:

- Students pick an animal, research the animal's habitat, and create a model of a specific physical adaptation suited for its habitat.
- Some examples of physical adaptations (or students can pick their own):
    - Lizards are the same color as the sand around them
    - Fish have fins to propel and steer in the water
    - Monkeys have strong, flexible tails to hang from branches
    - Giraffes have long necks to reach tender vegetation up high
- See the LEGO Engineering Animal Studies curriculum, Lesson 3 (page 20) for more ideas: http://www.legoengineering.com/images/stories/curriculum/REESE%20curriculum/LEcom_Compiled_Packet_Animals_LowRes.pdf
- Students can fill out the worksheet on page 95 in the LEGO Engineering curriculum above as they research the animal's habitat.

Construction Tips:

- Students can use the LEGO pieces to build their animal model, or supplement with other construction and crafts materials.
- This is primarily a building activity, and does not necessarily require programming or use of the NXT brick.
- Students can easily overestimate what they can build and models can quickly become too complex. Encourage the students to plan out their model before building and find ways to simplify or scale it down.

Discussion Questions:

- What makes a habitat? What are the common features of all habitats? What things do all animals need in their habitat?
    - A habitat is a place where animals live. For any animal to survive, they need air/oxygen, water, food, and enough space to move.
- Why is this animal a good match for its habitat? How does this physical trait of the animal help it survive in its habitat?
- Why would an animal without this trait have a harder time surviving in that habitat?
- How do other animals survive in this particular habitat?
- How easy was it to build the animal's trait with the materials available?
- How is your model similar to the real animal? How is it different?

2. DEFENSIVE BEHAVIOR: HERD OF CARIBOU SCATTERING

Goal: To program a caribou herd's defensive behavior of scattering in response to predators. Each group will build a robotic caribou that runs in a random direction or pattern at the sound of the 'predator'. Putting all the students' robots together will form the herd behavior.

Main Themes:

- Using the sound sensor (microphone)
- Adjusting the volume threshold that triggers action
- Animals' defensive behaviors

Biology Theory: Some prey animals, particularly the fast ones, try to escape their predators by running away. Many herd animals scatter, or run in a variety of directions, so that the predators cannot catch multiple members of the herd. Caribou (also known as Reindeer) live in large herds and use this scattering defensive behavior, as do cattle. Deer tend to live in small herds or individually, but also scatter in response to danger.

Robotics Theory: A threshold is a triggering point or value at which a state is changed or an effect is produced. Sound waves travel through the air and are picked up by the microphone sensor, which detects sound volume levels. A program takes a certain action when the sound volume reaches a specified level. The caribou robots pick up the sound of the 'predators', and when the sound reaches a certain volume threshold, they respond with the action of running away.

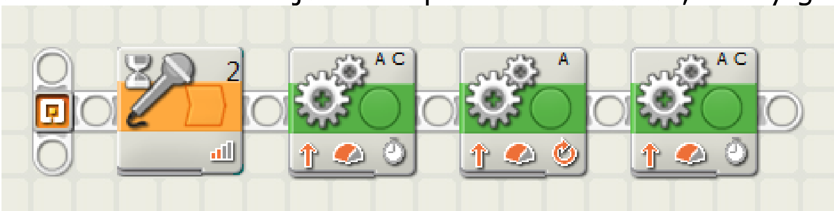
Activity Instructions:

- Put all the robots near each other facing outward so that they run into each other less often when they scatter.
- Experiment with various thresholds and test out the limits of the sensors. This is an important part of scientific research.
    - The whole class should make a noise at the same time to trigger the herd's defensive behavior. Try different types of sounds (clapping, stomping, singing, etc) and try it at different volumes (whispering to yelling).
    - Try setting the volume threshold at different levels to see what triggers the robot's action. Different groups can use different volume thresholds to simulate a more random herd behavior.
- Every robot should be programmed with a unique pattern of behavior. However, all the behaviors should be trying to move away from their starting point.

Construction Tips:

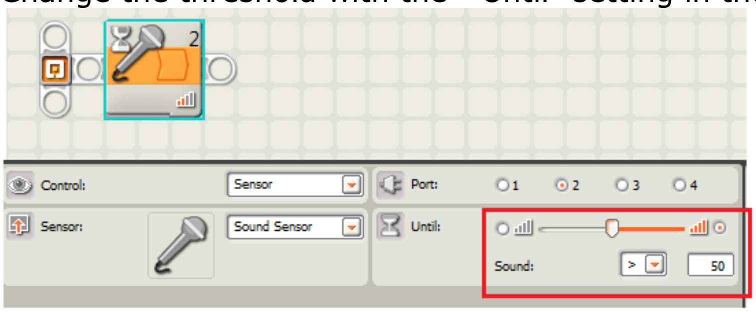
- The students can use a simple wheeled robot for this activity, or build something more elaborate to resemble caribou.
- For good step-by-step instructions of a simple 2-motor wheeled robot, see pages 48-59 of the LEGO Engineering curriculum: http://www.legoengineering.com/images/stories/curriculum/REESE%20curriculum/LEcom_Compiled_Packet_Animals_LowRes.pdf

Sample Code:
This sample robot hears the predator's sound and is programmed to drive away, then turn, then drive more. This is just one possible behavior; every group should construct their own.



This program:

- Waits for a sound that crosses the specified threshold
    - Change the threshold with the "Until" setting in the "wait for sound" block



    - Greater-than setting (>): robot waits for sound to be louder than that value to act
    - Less-than setting (<): robot waits for sound to be quieter than that value to act
- Drives forward for 2 seconds
- Turns to the side (by having just one motor run)
- Drives forward for 2 more seconds

Discussion Questions:

- At what level did the sound threshold have to be to trigger your robot?
- Did clapping set it off? Yelling? Stomping?
- What examples of real robots use sound for communication?
    - Example of simple robotic behaviors listening for commands from humans: Some cell phones and cars can interpret voice commands to initiate phone calls and other actions. Another very simple example is the "clapper" that turns lights on and off based on the sound of a person clapping.
    - Example of robots using sound to give feedback to humans: the Roomba vacuuming robots use different beeping patterns to alert people that it is stuck, out of battery charge, or has completed cleaning.
    - You can research on the internet for other examples
- How well does the scattering behavior defend against predators? Does it do more to help the herd as a whole or individuals? What happens to the young or weak animals?
    - Scattering can help to confuse the predator(s) since all the animals are running in different directions. This behavior tends to leave the young or weaker animals of the herd more vulnerable.
- How do other herd animals defend themselves against predators?
    - For example, compare caribou to the muskox, which are large Arctic hooved animal. The largest members of a muskox herd form a defensive circle around the younger members and will charge oncoming predators.
- What animals prey on caribou? What do caribou eat? Describe a few levels above and below caribou in the food chain.

Activity Variations (optional):

- Build multiple caribou robots, each with a different threshold of sound level to trigger the robot. Work as a group to set them off one by one. The more robots that are involved, the harder it will be to successfully set them off one by one.
- See how low you can set the threshold and still be able to sneak up on the caribou robot to surprise it.

Resources:

- Defensive behaviors of herds: cattle vs. buffalo: http://journals.cambridge.org/download.php?file=%2FORX%2FORX42_01%2FS0030605308001105a.pdf&code=9cd2be04099177c75eecd461067b11c3
- *The Encyclopedia of Tracks and Scats*: http://books.google.com/books?id=9XOc2_u7z6cC&printsec=frontcover

3. DEFENSIVE BEHAVIOR: "PLAYING POSSUM"

Goal: To build a robot that only moves when the surroundings are silent. This models a possum's behavior of 'playing dead' in response to a predator.

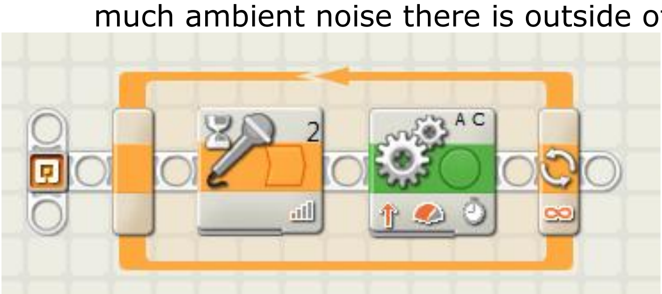
Main Themes:
- Using the sound sensor, or microphone, and adjusting the volume threshold
- Programming with loops
- Animals' defensive behaviors

Biology Theory: Animals in nature are very patient and cautious; some animals even act like they are dead. They mimic the appearance and smell of a dead animal with the hope that predators lose interest in what they think is less-than-fresh food. Opossums (a.k.a. possums), North America's only marsupial, actually go into shock and become unconscious when threatened, similar to fainting. Some species of snakes are very good at pretending to be dead.

Robotics Theory: See activity 2 "Caribou Scattering"

Activity Instructions:
- At a minimum, use a simple wheeled robot with a sound sensor attached. (see activity 2)
- Place the robots around the room, far enough apart that they won't run into each other. An open area is preferable.
- The whole class needs to be quiet together to trigger the possum robots. Experiment with different volumes and thresholds.

Sample Code:
- Each group should build a robot that stays still when it hears sound and moves when the sound is under a certain volume threshold.
- Students may need to test out different sound thresholds, particularly depending on how much ambient noise there is outside of the classroom.



This program:
- Waits until the sound level is below the specified threshold
  - Note: if you make the threshold too low, the sound of the motors could cross the threshold and cause the robot to stop moving.
- Turns the motors on to drive forward for 0.1 seconds
  - This is the determining factor in how quickly the program makes it through the loop. Operating the motors for 0.1 seconds means the program will loop about 10 times per second, which will make the robot more responsive to changes in noise.
  - Use the "coast" setting instead of "brake" to achieve a more fluid movement.
- Loops back to the beginning to check the sound sensor again

Discussion Questions:

- What volume threshold made the behavior work correctly?
- How well could the class keep quiet at the same time?
- What happens when/if you change the duration of the motors driving?
    - The longer that the motors are on and driving forward, the longer it takes to finish that iteration of the loop and go back to sampling the sound from the microphone. This can make the robot less responsive.
- How well does the 'playing dead' behavior work for animals' defense? What are the advantages or disadvantages?
    - It can discourage predators, many of whom avoid decaying carcasses.
    - However, it may not work against scavenging predators, who will eat carcasses. Also it may not help against the threat of being run over by automobiles.
- What other animals have similar defensive behaviors?
    - Many animals hide and freeze in response to danger. For example, turtles recede into their protective shell and don't move or come out until the threat is gone.
- What animals prey on possums? What do possums eat? Describe a few levels above and below possums in the food chain.

Resources:

- Opossum fact page: http://www.bbc.co.uk/nature/wildfacts/factfiles/658.shtml
- More detailed info on opossums: http://www.wildliferescueleague.org/report/opossum.html
- "Playing dead" info: http://amos.indiana.edu/library/scripts/possum.html

4. CAPTURING FOOD: VENUS FLYTRAP

Goal: To design and build a mechanical Venus Flytrap that captures food using a touch sensor. Responding to touch input from contact with an "insect", the jaws of the robotic Venus Flytrap snap closed and trap its food.

Main Themes:

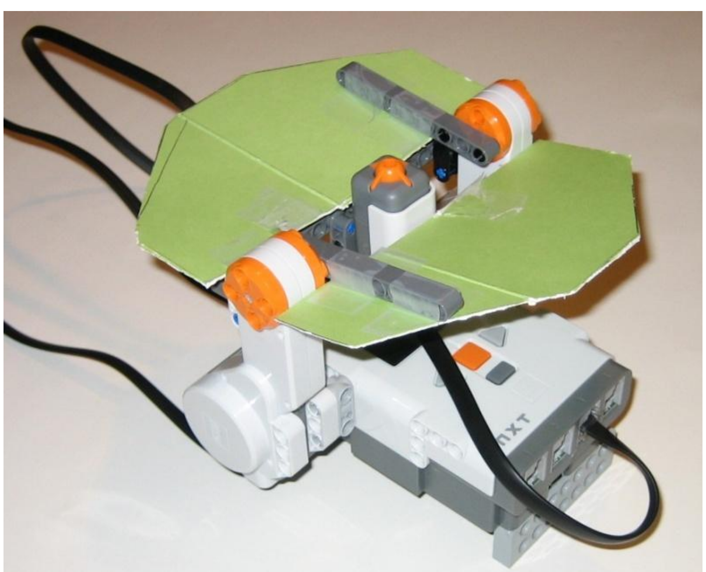
- Use of the touch sensor
- Construction of rotating mechanical parts
- Methods for capturing food

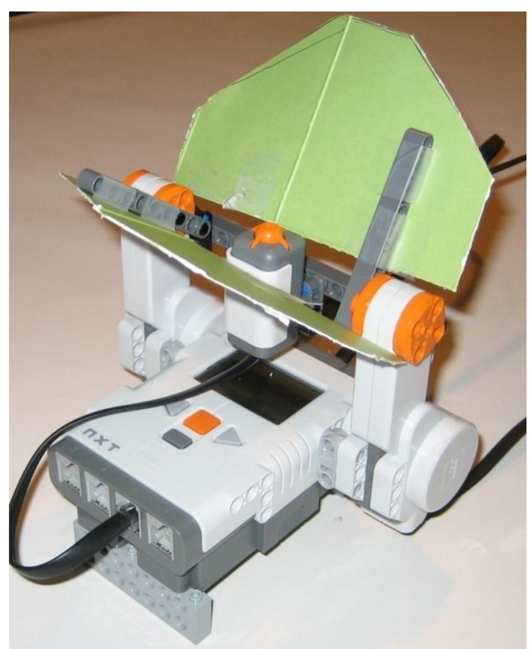
Biology Theory: Carnivorous plants trap insects and digest them with enzymes for nutrition. Venus Flytraps are one type of carnivorous plant. A single Venus Flytrap plant grows multiple traps. When an insect lands on an open trap, it triggers a reflex in the plant that causes the jaws of the trap to snap shut.

Construction Tips:

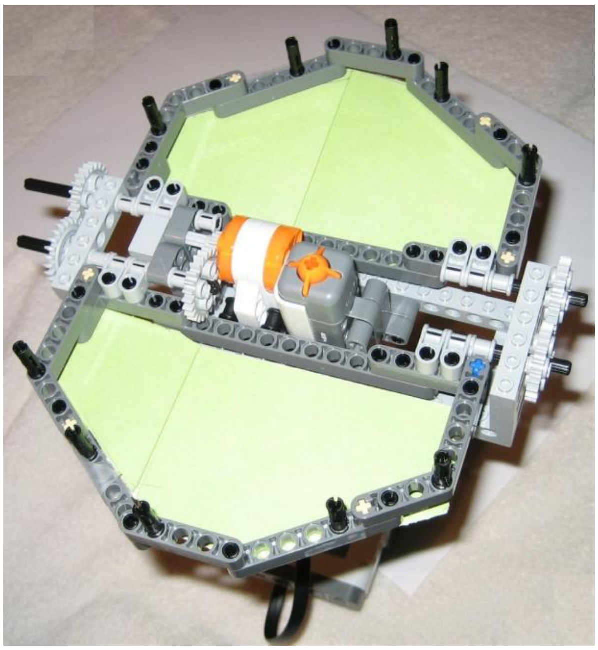
- Build a stationary robot that has 2 moving 'jaws' with a touch sensor in between. The jaws can be made out of paper, cardboard, or other material attached to the motor(s).
- Give the students time to design their flytrap before building it. Encourage them to iterate on the design and test it out as they go. Allow extra time for this design process.
- Students can pretend their finger is an insect and push the touch sensor to trigger the flytrap's response.

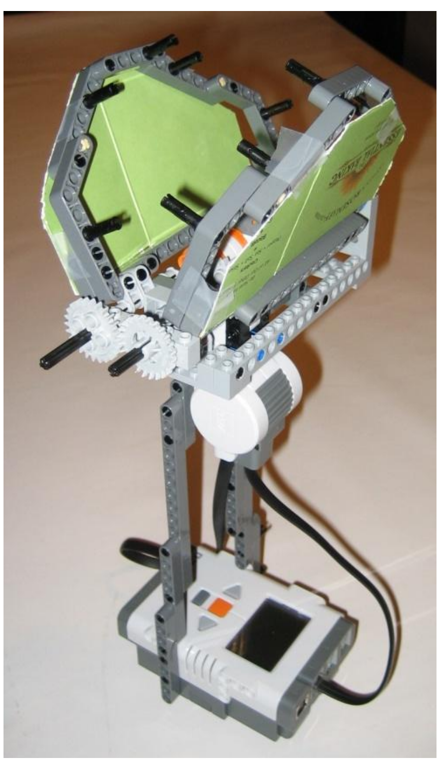
- Simple flytrap building tips:
  - Estimated building time: 2-3 hours
  - Use 2 motors attached to the NXT. Connect cardboard jaw sides onto the rotating motors with LEGO sticks & tape
  - Put a touch sensor between the 2 jaws
  - For an even simpler version, the motorized jaws and sensor can be taped to a cardboard base and sit alongside the NXT.

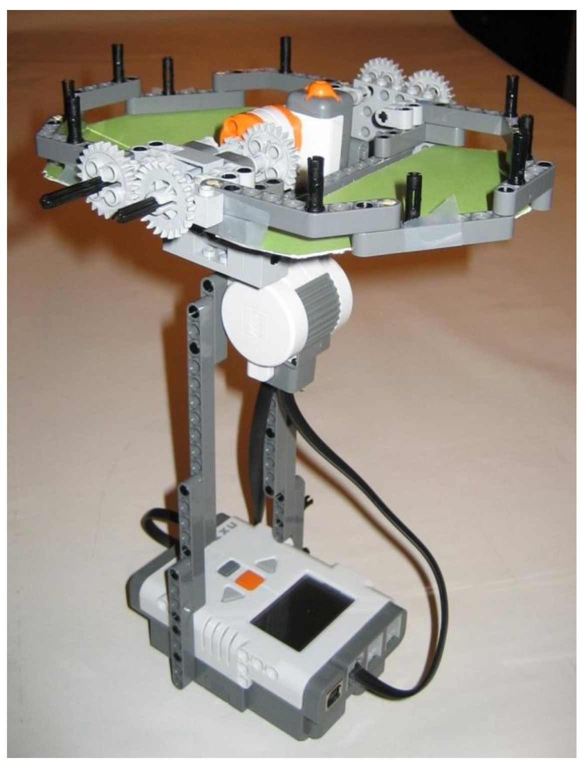




- More elaborate flytrap building tips:
    - Estimated building time: at least 3 hours
    - Use 1 motor. Connect the motor to 2 gears
    - Each gear connects to a 'jaw', made from a combination of LEGO frame and cardboard
    - Secure a touch sensor between the 2 jaws
    - Attach the full flytrap atop a "stem" of long LEGO pieces to the base NXT

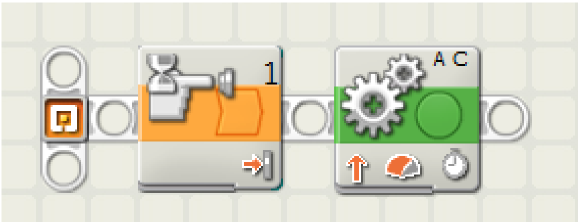






Sample Code:

- Turn the motor on for a set period of time, or a set number of degrees. Use trial and error to find the right amount of movement so that the motors consistently close the right amount.



This program tells the rover to:

- Wait for the touch sensor to be pushed
- Operate the motors for 1.5 seconds to close the plant's trap

Discussion Questions:

- How do most plants get their nutrition? What makes the Venus Flytrap different than most plants?
  - Most plants absorb minerals and other nutrients from the soil.
  - Venus Flytraps trap insects and digest them with enzymes to supplement the nutrients from the poor soil they usually live in.
- How does a Venus Flytrap sense touch? How is it similar or different than humans' touch?
  - Venus Flytraps have stiff hairs on their leaves that detect when an insect lands on the leaf. These hairs trigger a physical reflex that causes the flytrap to snap shut.
  - When our nerve endings detect an object in contact, it sends a message to our brain and we can interpret this sensory information and decide how to act. Flytraps, like all plants, do not have brains. However, sometimes the nerve information in humans goes straight to the spinal cord, causing a direct physical reflex, similar to the flytrap's system. This results in a quicker physical response to protect you from danger.
- What animals use behaviors like the Venus Flytrap to capture food?
  - Sea anemones wait for their food to come by and trap it with their tentacles.
  - Animal jaws and flytraps evolved to have similar characteristics. For example, alligators have big jaws that snap shut around their prey.
- What other methods do animals use to capture their food?
- How well does the Lego robot model simulate the plant's anatomy and method for capturing food? How does the model differ from the real plant?

Activity Variations (optional):

- Add to the program so that the plant opens its trap again after waiting for some period of time, and then waits for another insect to come along (using a loop).

Resources:

- Botanical Society of America's info on Venus Flytraps: http://www.botany.org/bsa/misc/carn.html

5. SONAR: ACT LIKE A BAT

Goal: To simulate a bat's use of sonar by using the ultrasonic distance sensor to move around the room. Students make a robot to take the ultrasonic sound and transform it into a lower pitched sound that we can hear.

Main Themes:

- Animal senses: echolocation
- Loops in programming
- Programming math

Robotics and Biology Theory: Both robots and animals use sonar to navigate around their immediate surroundings, often aided by other senses of sight and hearing. They emit a high pitched "chirp" and listen for the sound waves to bounce off an object in front of them. The longer it takes for the echo of the sound to return, the further away the object.

Bats, dolphins, and whales use sonar (a.k.a. echolocation) to detect objects in their environment. It is believed that Dolphin's teeth are arranged to help receive the incoming sound and make it easier for them to pinpoint the exact location of an object. Animals can also use echolocation for foraging or hunting for food.

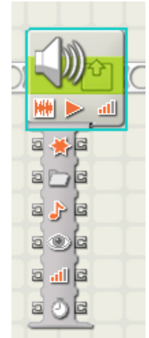
Robots use ultrasonic sensors in a similar way as animals to detect the distance to objects. Ultrasonic sensors use sound waves with a frequency above the limit of human hearing.

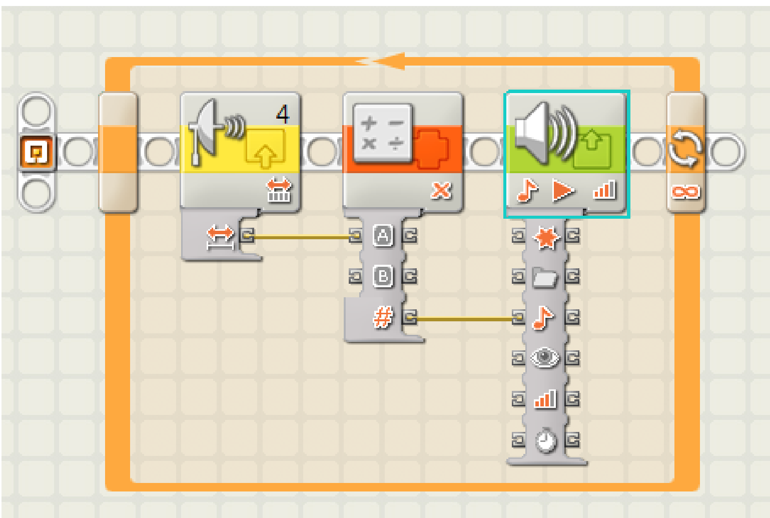
Activity Instructions:

- Students just need the ultrasonic distance sensor connected to the NXT
- Students walk around the room holding the ultrasonic sensor in front of them, trying to look down or close their eyes (walk slowly! A partner can follow along for safety and stop them before they hit an object).
- When they hear a lower pitched sound, an object is nearing – change direction!
- It's best to do this in a hallway or a clearing where walls are the only obstacles
- Students need to keep the sensor pointing directly ahead, as an angle can pick up either the ceiling or floor

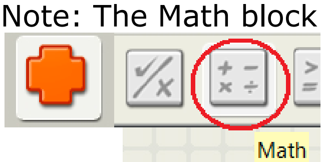
Sample Code:

- This program needs to use icons from the complete programming palette
    - At the bottom of the left toolbar of blocks, there are tabs for the "common palette", "complete palette" and "custom palette". Click the middle icon for the complete palette.

- Access all the inputs and outputs of the blocks by clicking on the expansion tabs at the bottom of the block.
    - Click at the bottom:  to expand the icon to look like this: 
    - Each spot on the expanded panel corresponds to either an input (setting) for that block or a value outputted by the block. When you move your mouse over each icon, you can see what it represents.
    - You can send values from one block to another. "Wire" an output value from the right side of a block to the input on the left side of another block (click the output and input squares to connect them with wires).



This program:

- Takes a reading output from the distance sensor.
    - Note: this is a different block than the more familiar 'wait for distance' block.
    - Go to the complete palette, and choose the ultrasonic sensor from the "sensor" group: 
- That output value is wired into spot "A" of the Math block. This value is multiplied by 5 (in the setting for "B").
    - Note: The Math block is on the complete palette, under the "data" group: 

    - When you click on the Math block, you can choose the multiplication operation and the value for "B" in the settings panel
    - The distance value needs to be multiplied to make it easier to hear small differences in distance. This sample programs uses a factor of 5; experiment with other factors to see what happens.
- The multiplied output is wired to the sound block as an input for the frequency of sound emitted
    - Uncheck the "wait for completion" setting on the sound block. This will cause the robot to resample the distance value more often
- Then the program loops back to the beginning to sample the distance sensor again

Discussion Questions:

- Were you able to walk around the room safely, using only the sound emitted by the NXT?
- How do animals use sonar to navigate?
- How well does sonar work for navigation in comparison to vision? What are its advantages and disadvantages?
    - Sonar can work in the dark, since it uses sound waves rather than light waves.
    - Vision can work over greater distances than sonar because light generally travels farther than sound. Sonar works well for orientation in the immediate environment and avoiding objects close at hand.
    - Soft materials absorb rather than reflect the sound and can interfere with sonar.
- How does an animal's use of sonar compare to the robot's ultrasonic sensor?
    - They are very similar. Both use sound waves to measure distance to an object.

Resources:

- Interactive resource on how animals use sonar as a sense, with sample sounds from bats and dolphins: http://www.biosonar.bris.ac.uk/
- More info on animal echolocation: http://en.wikipedia.org/wiki/Animal_echolocation
- Info on the use of underwater sonar in technology: http://en.wikipedia.org/wiki/Sonar

6. FAMILY BEHAVIORS: STAY CLOSE TO MOM

Goal: To build a baby elephant that attempts to stay in contact with its mother at all times. The robot uses a touch sensor and looped behavior to maintain the right distance from "mom".

Main Themes:

- Control Loops
- Construction of sensor modifications to increase accuracy
- Animal family behaviors

Robotics Theory: Control Loops attempt to maintain equilibrium. Robots take in data from their sensors and then adjust their behavior based on this data to try to match a predefined desired state. A classic example is the cruise control function of a car. The car is always trying to maintain a certain speed, and will adjust the engine power accordingly. In this activity, the baby elephant tries to maintain contact with its mother. The baby will use the state of its touch sensor to decide whether to keep moving forward, so that it maintains the 'pressed' state of its sensor.

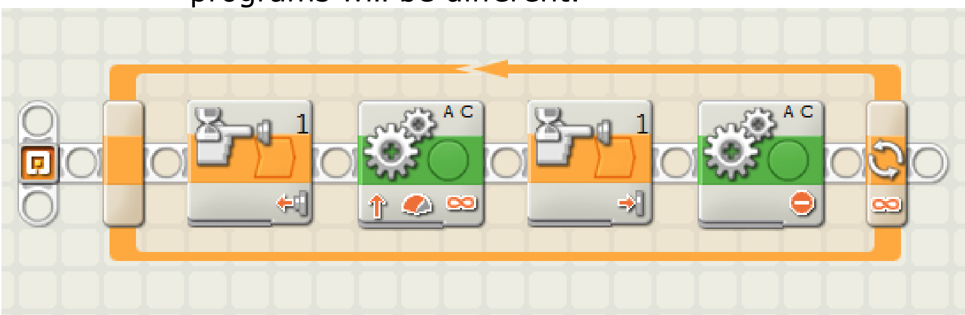
Construction Tips:

- At a minimum, use a simple wheeled robot with a touch sensor out front (see activity 2)
- Attach a bumper to the touch sensor so it can better detect when it has caught up to mom
    - For a simple bumper, you can attach a LEGO rod and wheel or gear to the front of the touch sensor

    - For a more elaborate bumper, see page 40 of the building instructions that come with the LEGO kits
    - Note: if the touch sensor does not get "pressed" reliably, try making a lighter bumper or shortening the connection between the bumper and touch sensor
- The students can play "mom" using a thick piece of cardboard, leading the baby robot at varying speeds.

Sample Code:

- This baby robot starts in contact with mom, and then mom walks away.
  - Students can also program the baby to start away from mom and catch up to her (moving until the sensor is pressed).
  - The initial setup needs to be decided before beginning to program because the programs will be different.



This program tells the rover to:

- Wait for the touch sensor to be released
- Moves forward until…
- The baby robot catches up to mom and touch sensor is pressed
- Stops moving, since it's back in contact with mom
- Loops back to the start

Discussion Questions:

- Was the baby robot able to stay with the mom? Did it veer off track?
  - If the baby robot turned slightly and was not able to stay in line with mom, check that both wheels can move freely.
- Did the baby ever "crash" into mom?
  - Try building a bumper for the touch sensor so it can be triggered by a wider contact area.
- What happens if "mom" turns? Did the baby keep up? Why or why not?
- What is the family structure of elephants?
- Why is it important for baby elephants to stay close to their mom?
- What other animals grow up with a family? What animals are not raised by their parents?

Activity Variations (Optional):

- Design a mother elephant robot, which leads the baby elephant

7. COLD BLOODED ANIMALS: IGUANA-BOT

Goal: To build an iguana that responds to brighter light by moving faster.

Main Themes:

- Using the light sensor to provide collected data for a control loop
- Cold blooded animals

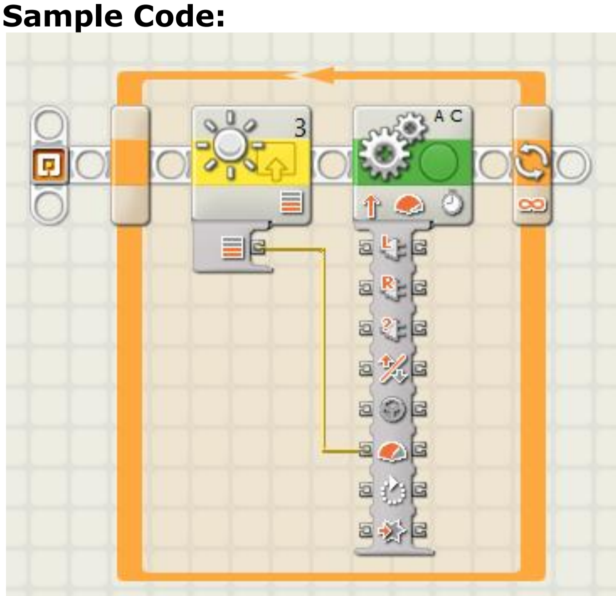
Biology Theory: Warm blooded animals, including humans, have bodies with internally regulated temperatures. Cold-blooded animals, such as the iguana, have to actively regulate their temperature by seeking out sun or shade. This behavior is a control loop; they manually maintain an acceptable body temperature.

Scientists actually don't use the term "cold-blooded" anymore, as it incorrectly implies that these animals never experience high body temperatures. Instead, scientists classify animals based on the "ectothermic" trait of regulating internal temperatures by external means, such as the sun. Some ectothermic animals, including iguanas, also exhibit the behavior of lowering their metabolism rates and moving slower or hibernating when their heat source is not available (at night) or lessened (in the winter).

Activity Instructions:

- Build at least a simple wheeled robot. (see activity 2)
- Point the light sensor up in the air to make it easier to shine a flashlight directly on top.
- Students should point the flashlight directly at the light sensor to make the iguana move. The closer the flashlight, the faster the movement. Holding the flashlight farther from the sensor causes the iguana to slow and stop.
- You may need to close window shades and turn off the lights to darken the room.

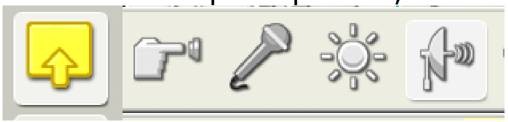
Sample Code:



This program:

- Takes a reading from the light sensor
    - Note: this is a different block than the more familiar 'wait for light' block.

- Go to the complete palette, and choose the light sensor from the "sensor" group:



- Wires that light value output into the motor's speed icon
    - Remember, you can access all the inputs and outputs of the blocks by clicking on the expansion tab at the bottom of the block. (see activity 5)
    - Use a small value (e.g. 0.1 seconds) for the duration of the motors running so that the robot loops through the program quickly. This will make it more responsive to changes in light.
    - Use the "coast" option instead of "brake" so the movement is smooth
- Loops back to the beginning

Discussion Questions:
- What other animals are ectothermic?
- What is the iguana's source of heat?
    - Sunlight provides the heat to increase their body temperature.
- How do iguanas and other lizards animals behave during the day vs. night?
    - During the day, these animals are much more active than at night
- How dark did you have to make the room for the robot to work as intended?
- What happens when you shine the light on the robot from a close versus far distance?
    - The closer the flashlight, the faster the robo-animal moves.
- How is this behavior a control loop? What is the iguana trying to maintain?
    - This program repeatedly samples its light sensor to determine the speed of its movement. The Iguana-bot is trying to maintain a certain speed relative to the level of light (which the student can vary).
    - In the wild, iguanas and other lizards move into or out of the sunlight to maintain their body temperatures.

Activity Variations (optional):
- Play a sound tone corresponding to the light intensity.

Resources:
- More info on lizards: http://www.bbc.co.uk/nature/wildfacts/factfiles/282.shtml
- More info on 'cold-blooded' animals: http://en.wikipedia.org/wiki/Cold-blood

8. INSTINCTUAL BEHAVIORS: SEA TURTLES

Goal: To build a baby sea turtle that finds its way to the ocean after hatching by moving towards light reflecting off the water. Each group will program a robot that locates and homes in on a flashlight.

Main Themes:

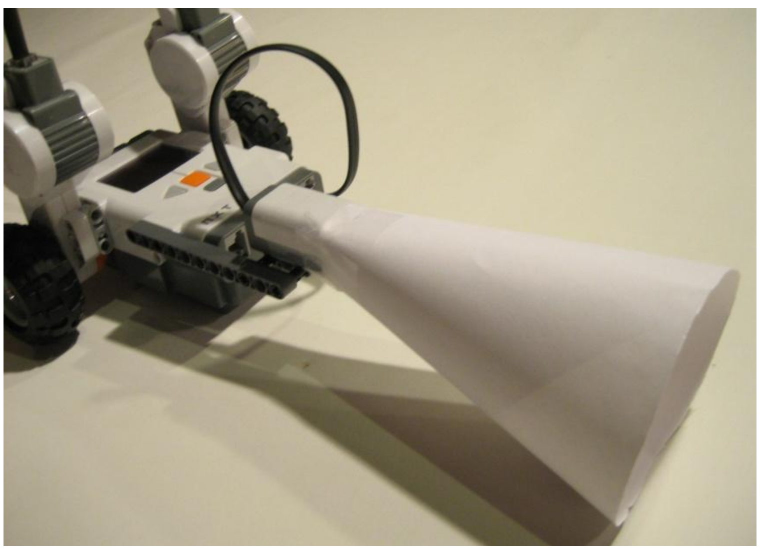
- Using the light sensor, and modifying the sensor to increase its accuracy
- Increasingly complex programming logic using control loops
- Adjusting thresholds of a system
- Animal instincts

Biology Theory: Animals are born with certain ingrained behaviors that they naturally exhibit. These instincts are not based upon prior experience and do not depend on emotion or learning. When sea turtles hatch from their eggs on the beach, they instinctively move towards the lightest horizon, which is in the direction of the ocean. They hatch at night and can sense the glimmering of the ocean to crawl towards it. Communities near sea turtle hatching grounds have to make sure they turn lights off during hatching season so the turtles don't run the wrong way.

Robotics Theory: This activity is another example of a control loop. The sea turtle robot tries to maintain a direction towards the brightest light. Using the light sensor to measure intensity, the sea turtle will turn to adjust its direction.

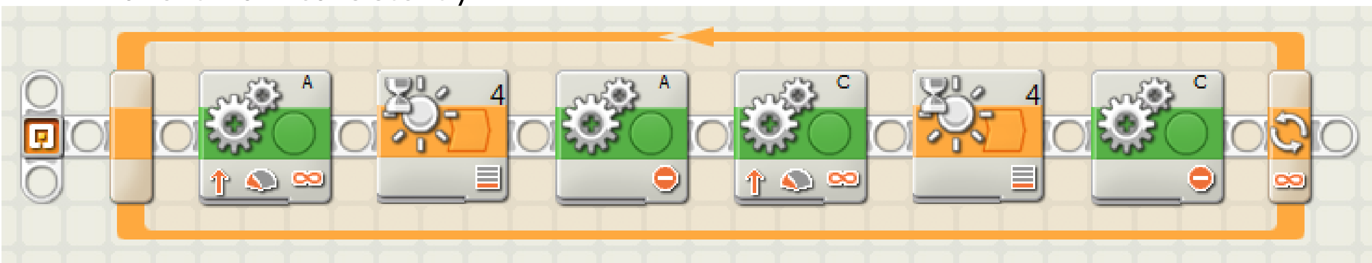
Construction Tips:

- Point light sensor forwards on a simple wheeled robot (see activity 2), or build a more elaborate 'turtle' robot
- You'll probably need to pull the shades down and turn the lights off to get this to work (unless your flashlight is incredibly bright).
- Build a small paper cone around the light sensor. This is needed to make sure the light sensor only views a limited area, which will increase its accuracy at detecting the direction of the flashlight. The cone should be about the size and shape of an ice cream cone, and can be taped onto the light sensor. Darker paper works better, but white notebook paper can also be used.



Sample Code:

- The turtle robot moves forward in a zigzag manner, changing direction as the light sensor crosses a specified threshold.
- Use the "view" mode on the NXT to look at the values of the light sensor when it's pointing at the flashlight and away. This will give a good starting point for the light sensor threshold. Students probably need to tune the threshold further through trial and error to make it work consistently.



This program tells the rover to:

- Turn on motor A to turn in one direction
- Wait for the light to cross a specified threshold (greater than the threshold)
- Turn off motor A
- Turn on motor C to turn in the other direction
- Wait for the light to fall below the threshold (less than the threshold)
- Turn off motor C
- Loop back to the beginning

Discussion Questions:

- How successful was the robot at finding the light? What was the threshold you set to make it work?
- How many iterations of setting different thresholds did you have to go through?
- What other animals exhibit this type of instinctual behavior of moving towards light?
    - For example, moths move towards light and flame
- What are other animal instinctual behaviors?
    - Every animal has instinctual behaviors; here are a couple examples:
    - Bees communicate the direction of a food source through ingrained dance-like movements.
    - Some birds instinctually know how to build a nest and migrate.
- What instinctual behaviors are humans born with?
    - Human babies have many instinctual reflexes. For example, they will curl up their fingers and grasp objects in their palm.

9. GROUP BEHAVIORS: BABY DUCKS

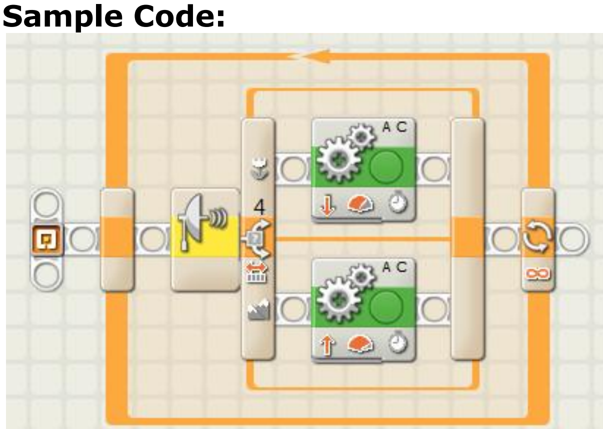
Goal: To build a robotic baby duck that follows mom a set distance apart. Combine multiple duck robots to have a chain of baby ducks following a leader.

Main Themes:
- "Switches" in programming
- A control loop that monitors the distance to the duck ahead
- Modifying the robots to increase the accuracy of the sensors
- Movements of animal groups

Robotics Theory: Using a "switch", the robot can decide between two different actions at the same time based on how the sensor value compares to the threshold. The robot takes one action if the sensor value is above the threshold and takes a different action if the value is below the threshold. In other programming languages, a "switch" is called an "if-then-else" statement.

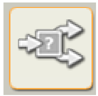
Activity Instructions:
- Before building their robots, the students can act this activity out using the view screen and forming a line. This can help them figure out how to program the robot.
    - Each student holds the NXT with the distance sensor attached and pointed forward to the back of the student in front of them.
    - Using the "view" mode on the NXT, the students try to stay a set distance away from the person in front of them. Try to stay a foot away from the person in front.
    - One student acts as the leader, changing speeds and stopping.
    - Each student should reason out their internal logic as they do this activity and use this to plan out their code. (i.e. "if I'm closer than a foot, I backup. If I'm farther than a foot, I move forward")
- At a minimum, build a simple wheeled robot with ultrasonic distance sensor facing forward (see activity 2). Or build LEGO structures to resemble a duck.
- Tape the cardboard list of Lego pieces onto the back of your duck so that it's easier for the duck behind it to sense it.
- A student can act out the part of the mommy duck. She/he should hold a piece of cardboard (the list of Lego pieces works well) in front of the first baby duck, leading it down the hall. The student playing mom can vary speed and start/stop at various times.
- First test out one duck at a time and iterate until it follows "mom" individually. Then the groups can work together to chain their ducks in a line.

Sample Code:



This program tells the rover to:

- Uses a switch to take a reading from the distance sensor and compare it to a specified value
  - The switch block is at the bottom of the common palette:

    
  - In the switch block's settings, change the sensor it uses to the ultrasonic sensor.
  - This is also where you enter the threshold value that the switch compares the distance value to (i.e. the distance you want the duck to stay behind mom).
  - Experiment with different distances. A good starting point is 12 inches.
- If the measured distance is less than the specified value, then the robot backs up. This path of the switch is on top, denoted by the icon of an up-close flower.
- If the measure distance is greater than the specified value (meaning the duck is too far from mom!) the robot drives forward quickly to catch up. This path of the switch is on the bottom, denoted by the icon of mountains far away.
  - Use a small value (e.g. 0.1 seconds) for the duration of the motors running so that the robot loops through the program quickly. This will make it more responsive to changes in mom's movement.
  - Use the "coast" option instead of "brake" so that the movement is smooth
- Then the program loops back to the beginning to check where mom is again.

Discussion Questions:

- As mom varies speed and stops, how do the ducks respond?
- How is this behavior a control loop? What are the ducks trying to maintain?
  - The duck uses the distance sensor value to decide whether to keep moving forward
  - It maintains the specified threshold of distance from the duck in front
- Can you outrun the baby ducks? What happens when you do?
  - If mom moves more quickly than the robo-ducks and gets far enough away, the distance sensor will be more likely to pick up other objects and lose mom. Also, mom may become out of range of the limits of this distance sensor.
- How was this program similar to or different from the "Stay close to mom" activity?
  - The "stay close to mom" activity uses a touch sensor instead of a distance sensor
  - Both activities functionally have the same behavior of moving more or less depending on where mom is
  - The "stay close to mom" program looks for one state of the touch sensor (released), responding by moving, and then looks for the other state of the sensor (pushed) in order to stop. That program only decides whether or not to execute a single behavior at a time.
  - The duck activity reads a value from the distance sensor and then decides whether to move forwards or backwards, using a switch. This is a more advanced programming structure because it decides between two behaviors at the same time.
- What other animals move in groups and how do they do so?
  - Discuss schools of fish, swarms of ants, and/or flocks of birds

10. CULMINATING PROJECT: DESIGN YOUR OWN ROBO-ANIMAL

Goal: Students create their own fictional, but believable, animal. They choose a habitat and design the physical characteristics, senses, and behaviors of an imaginary animal that would be able to live in this habitat. Students need to logically explain how this animal would survive in that habitat in writing and/or class presentation.

Main Themes:
- Iterative design
- Demonstrate knowledge of animal adaptations, behaviors and senses from the whole unit

Activity Instructions
- Students first choose a real habitat on Earth (e.g. rainforest, desert, mountains, etc)
  - Students research their chosen habitat to understand how animals survive there
  - They can fill out the worksheet on page 95 in the LEGO Engineering Animal Studies curriculum as they research the animal's habitat: http://www.legoengineering.com/images/stories/curriculum/REESE%20curriculum/LEcom_Compiled_Packet_Animals_LowRes.pdf
- Students then design their fictional animal to live within this habitat.
  - Students should plan out their robo-animal before building (e.g. a journal or sketching assignment).
  - At a minimum, students should build a simple wheeled rover robot. They can add LEGO structures, cardboard cutouts, fake fur, feathers or other types of crafts for the animal's physical features.
  - For a more advanced activity, students can design functional physical features from LEGOs (e.g. moving jaws or wings).
- Students program at least 3 behaviors that fit into one of the following categories:
  - Habitat adaptation
  - Defensive behavior
  - Behavior for finding or catching food
  - Family behaviors for raising young
  - Behavior in response to sensory input
  - Instinctual behavior
  - Group movement
- Note: each behavior should be a separate program their robo-animal can run

Writing assignments (optional):
- Explain how and why this fictional animal would be able to survive in its habitat
- Refine the robo-animal design in several iterations. Keep track of each iteration in a journal, sketching the plans and describing the reasoning behind each round of changes.

Activity Variations (optional):
- Groups pair up to program behaviors of their robo-animals interacting
  - The groups should decide together what one robo-animal is going to do and how the other robo-animal responds
  - Note: these can be similar to the interactions explored in previous activities, such as detecting the sound of a predator or staying close to mom with the touch or distance sensors