Science News

EDUCATOR GUIDE

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February 16, 2019

Robot Re-creates a Tetrapod's Moves

SOCIETY FOR SCIENCE & THE PUBLIC

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Robot Re-creates a Tetrapod's Moves

About this Guide

Scientists used a variety of techniques to figure out how a four-legged animal walked nearly 300 million years ago. Use this Guide to introduce students to the ancient tetrapod *Orobates pabsti* and the evidence it left behind. Students will learn how scientists combine approaches from scientific fields — including biology, physics, robotics and computer science — to study ancient locomotion. Students will also apply their knowledge of experimental design, human biology and physics to investigate classmates' locomotion.

This Guide includes:

Article-based observation, Q&A — Students will answer questions based on the *Science News* article "Robot re-creates a tetrapod's moves," Readability: 14.1. Questions ask students to summarize what scientists learned about tetrapod locomotion and to consider patterns and structure and function. Another version of the article, "Four-legged robot might show how ancient creature walked," Readability: 8.5, appears on *Science News for Students.*

> **Article-based observations, questions only** — These questions are formatted so it's easy to print them out as a worksheet.

Cross-curricular connections, Q&A — Use these questions to help students put themselves in the shoes of scientists studying ancient locomotion. After dividing students into groups based on research approach, encourage them to apply their knowledge of experimental design to answer the discussion prompts. Prompts cover concepts in biology, physics, robotics and computer science.

> **Cross-curricular connections, questions only** — These questions are formatted so it's easy to print them out as a worksheet.

Activity: Tracing tracks and guessing gaits

> **Purpose:** This activity will help students understand how scientists can make inferences and construct explanations about animal movement by analyzing those animals' tracks. Students will use what they know about human range of motion, gravity, friction and balance to analyze classmates' trackways and try to infer how their classmates made the unfamiliar tracks.
>
> **Approximate class time:** One class period.

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Standards

Next Generation Science	**Common Core ELA**
Motion and Stability: Forces and Interactions: HS-PS2-1, HS-PS2-2	Reading Informational Text (RI): 1, 2, 4, 5, 7
Energy: HS-PS3-3	Writing (W): 1, 2, 3, 4, 6, 7, 8, 9
Ecosystems: Interactions, Energy, and Dynamics: HS-LS2-2	Speaking and Listening (SL): 1, 2, 4, 5, 6
Heredity: Inheritance and Variation of Traits: HS-LS3-2	Reading for Literacy in Science and Technical Subjects (RST): 1, 2, 3, 4, 5, 7, 8, 9
Biological Evolution: Unity and Diversity: HS-LS4-2, HS-LS4-3, HS-LS4-4, HS-LS4-4	Writing Literacy in History/Social Studies and Science and Technical Subjects (WHST): 1, 2, 4, 7, 8, 9
Engineering Design: HS-ETS1-2, HS-ETS1-4	

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Article-Based Observation, Q&A

Directions: Have students read the article "Robot re-creates a tetrapod's moves" and answer the following questions.

1. What is *Orobates pabsti* and how is the creature related to humans?

O. pabsti is a four-legged species that lived between 280 million and 290 million years ago. *O. pabsti* is an early amniote, a member of the group that includes all reptiles and mammals (including humans) living today.

2. Why are scientists interested in how *O. pabsti* walked?

Understanding how early amniotes walked on land can shed light on the evolution and diversification of amniotes more generally. It also provides clues to how different styles of walking evolved over time.

3. Why is the amniotic membrane considered a "key evolutionary innovation"?

This protective membrane surrounds an embryo and allows animals to bypass the tadpole stage of life. That means these animals can survive entirely on land. The ability to survive entirely on land opened new habitats for organisms to colonize and led to new evolutionary opportunities, and pressures.

4. What techniques did scientists combine to try to understand how *O. pabsti* moved?

The study of *O. pabsti* relied on a combination of several tactics — re-creating the skeleton, creating digital and robotic simulations and studying modern species.

5. Why were the conclusions about *O. pabsti*'s gait surprising?

O. pabsti appears to have held its belly off the ground and didn't have too much side-to-side movements. Scientists were surprised because they expected this walking style to be found only in more modern four-legged creatures.

6. Based on clues from the article, what does it mean for a gait to be efficient?

Having an efficient gait means the animal spent minimal energy to get from place to place. The animal would be balanced without a lot of slipping or sliding, so as not to waste energy on side to side movements or unnecessary steps.

7. What other research questions related to ancient locomotion might benefit from the approach these researchers used?

Other puzzles of ancient locomotion include how the first birds flew and how human ancestors began walking upright.

8. Identify one word in the article that is unfamiliar and define it from context.

Gait: The sequence of movements that get something from one place to another.

Trackways: Prints left in the ground by a creature as it moves from one place to another.

9. Watch the video provided in the online version of the article, "A four-legged robot hints at how ancient tetrapods walked." What is one piece of information that appears in both the article and video? What information is in the video but not in the article?

In the video, we see OroBOT moving as it was described in the article. The video gives a sense of how fast OroBOT walks, which isn't explicitly described in the article.

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Robot Re-creates a Tetrapod’s Moves

Article-Based Observation, Q

Directions: After reading the article “Robot re-creates a tetrapod’s moves,” answer the following questions.

1. What is *Orobates pabsti* and how is the creature related to humans?

2. Why are scientists interested in how *O. pabsti* walked?

3. Why is the amniotic membrane considered a “key evolutionary innovation”?

4. What techniques did scientists combine to try to understand how *O. pabsti* moved?

5. Why were the conclusions about *O. pabsti*’s gait surprising?

6. Based on clues from the article, what does it mean for a gait to be efficient?

7. What other research questions related to ancient locomotion might benefit from the approach these researchers used?

8. Identify one word in the article that is unfamiliar and define it from context.

9. Watch the video provided in the online version of the article, "A four-legged robot hints at how ancient tetrapods walked." What is one piece of information that appears in both the article and video? What information is in the video but not in the article?

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Robot Re-creates a Tetrapod’s Moves

Cross-Curricular Connections, Q&A

Directions: After reading “Robot re-creates a tetrapod’s moves,” students can apply their knowledge of experimental design to answer the discussion questions provided. The questions encourage students to put themselves in the shoes of scientists studying ancient locomotion. Scientific investigations of ancient locomotion cover concepts in biology, physics, robotics and computer science.

Suggestion for structuring discussion: Divide the class into four groups and review the four research approaches used to study *Orobates pabsti* listed below. Assign each group one of the research techniques and provide the groups the discussion prompts one at a time. Allow about three minutes for each group to discuss each prompt. Students should summarize their answers for other groups before moving on to the next prompt.

Research approaches:

A. Re-created an *Orobates pabsti* skeleton from well-preserved fossils found in Germany.

B. Developed a computer simulation that explored hypothetical motion based on the *Orobates pabsti* skeleton.

C. Studied how modern-day tetrapods including salamanders, skinks, caimans and iguanas walk.

D. Created a robot to act out potential gaits and match those gaits to fossil trackways.

Discussion prompts:

1. What background knowledge would you need to complete the specified research approach? What type of prior research experience and/or fieldwork would have been helpful?

A. Skeleton re-creation: Knowledge of anatomy, paleontology and biomechanics would be needed to complete the approach. Prior research experience handling and preserving fossils would be helpful.

B. Computer simulation: Knowledge of computer science, modeling, physics and biomechanics would be needed to complete the approach. Prior experience coding and modeling biological systems would be helpful.

C. Studying modern-day tetrapods: Knowledge of anatomy and evolutionary biology, including phylogeny and adaptation, would be needed to complete the approach. Knowledge of the animals’ environment, ecology, life history and behaviors would also be useful. Prior experience handling such animals or observing them in the wild would be helpful.

D. Robot: Knowledge of engineering, robotics, computer science, physics and experimental design would be needed to complete the approach. Prior experience building animal-inspired robots would be helpful.

2. What type of data would you get from this research approach and what insight might that data offer?

A. Skeleton re-creation: Scanning fossils would yield data about the animal's size and shape and how bones connect at joints. Analyzing how bones fit into joints and the size and number of joints can offer clues to range of motion, which would constrain possible gaits.

B. Computer simulation: Computer simulations could yield data on power expenditure, balance, stability and the force exerted on the ground with each step (ground reaction force) for different gaits. Simulations allow you to analyze a lot of factors in tandem to see what combinations of characteristics make physical sense.

C. Studying modern-day tetrapods: Observing modern-day tetrapods walking could yield data on the animals' limb sprawl, body height, balance and the ground reaction force with each step. Observing animals in their natural environment could also reveal how they move in different scenarios: when running away from predators or chasing prey, or when climbing or moving through water. In analyzing this data, you could look for patterns between body size or body mass and movement. With phylogenetic information, you could try to understand how tetrapod gaits evolved over time.

D. Robot: The robot would produce different gaits depending on inputs for balance, energy consumption, frequency, limb placement, spine bending and body height, among other factors. Having the robot act out different gaits might allow you to rule out gaits that don't match the trackways or might lead to toppling on different types of surfaces.

3. Come up with a possible hypothesis about a tetrapod's gait that could be tested via the approach. State specifically whether your hypothesis applies to modern or ancient tetrapods. What is a possible result relating to the hypothesis?

A. Skeleton re-creation: A student might hypothesize that the ancient tetrapod's joints didn't allow for much rotation of the legs. If that hypothesis is true, the animal's spine might have had to move from side to side as it walked.

B. Computer simulation: Students might hypothesize that the most energy-efficient gaits of ancient tetrapods come from a tetrapod that stays close to the ground, or that animals that stay close to the ground can move faster. The simulation might reveal these hypotheses to be true or false, or might show that the validity of the hypothesis depends on other factors such as animal size and force applied to the ground with each step.

C. Studying modern-day tetrapods: Students might hypothesize that the speed of modern-day tetrapods correlates with their style of walking (diagonal walk versus pacing versus trot). By looking for patterns in how modern-day tetrapods walk depending on their body size and form, students might gain clues to how ancient tetrapods walked.

D. Robot: Students might hypothesize that a gait that best matches the ancient O. pabsti *trackway wouldn't include much side-to-side movement. Based on data collected during the investigation, students might find that the gaits lacking side-to-side movement would also help the tetrapod conserve energy.*

4. What gaps in knowledge would you still have following the investigation? What additional approach could help you fill in the gaps?

A. Skeleton re-creation: Studying a reconstructed skeleton might give scientists an idea of the range of possible tetrapod movement, but it couldn't pin down a specific movement among the options. Encourage students to think about other characteristics that aren't preserved and how those characteristics might affect movement. For example, the amount of muscle, fat or other tissue might influence balance and thus gait. An approach that could help fill that knowledge gap would be to study how the gaits of modern-day tetrapods differ based on body composition.

B. Computer simulation: Simulations can give scientists a better idea of how the ancient tetrapod would have walked, but simulations often rely on scientists' assumptions. For instance, many locomotor simulations assume that the most likely gaits have the lowest energetic cost over a given distance. But that singular goal can lead to extremely unrealistic gaits. Gaps that might improve a simulation include data about the animal's physiology, including metabolism and energy requirements.

C. Studying modern-day tetrapods: Modern-day tetrapods helped scientists figure out the possible range of motion for O. pabsti*, but scientists would need to know how* O. pabsti*'s body differed from modern-day tetrapods' bodies. Differences between the life histories and environments of* O. pabsti *and modern tetrapods might also affect movement. With computer simulations, scientists could see how different factors may impact gait.*

D. Robot: Even if scientists zero in on O. pabsti*'s walking style, there are still unanswered questions: How did the walking style evolve? Was it a novel innovation for* O. pabsti*'s lineage? Conducting a similar investigation with older fossils in* O. pabsti*'s lineage, if they exist, might provide clues to the evolution of this walking style.*

5. Scientists used this research approach to study the locomotion of an extinct species. What other types of research questions in other fields currently benefit or could benefit from the approach your group studied? Look up information, if needed, to give an example.

A. Skeleton re-creation: Scientists can learn much more about an animal than its locomotion from studying re-created skeletons. Researchers can gain clues to size of individuals, variation among individuals and how the body might have developed over time. Reconstructed skeletons might also provide clues to how an animal lived. Fossils themselves also offer info: Where the fossil was found and the rock it is encased in can be useful for pinpointing the fossil's age. Biologists can use their knowledge about living things to learn more about how fossils are related to each other. And in areas where fossils are relatively abundant, such as the Burgess Shale in Canada, counts of individuals and species offer clues to population sizes and how these creatures were dispersed across the ancient world.

B. Computer simulation: Many other fields of science build computer simulations in an attempt to answer research questions. Some of those fields include physics, biology, astronomy and meteorology. Meteorologists, for example, build computer simulations from climate data and past weather patterns in an attempt to predict future weather.

C. Studying modern-day tetrapods: Studying modern-day animals can be useful for engineers. For instance, studying birds' high-speed turns may help scientists design drones that can pull tight maneuvers in crowded places. And bioengineers have mimicked mantis shrimp vision to build advanced cameras. Encourage students to think about other examples of bioinspired technology, as well as all the questions biologists can answer by studying animals.

D. Robot: Scientists that study modern-day marine organisms also find animal-inspired robots useful. For instance, deep-sea physiologists have used robots to understand how a snailfish can withstand intense pressure and extremely cold temperatures. Animal-inspired robots can also be put to use accomplishing dangerous tasks. For instance, an inchwormlike robot equipped with octopus-inspired suction cups can scale walls. The bot might someday help conduct surveillance or inspect buildings and bridges. And a tiny insect-inspired bot can fly, swim and launch itself from water. Such a bot could one day be used to perform search-and-rescue operations or sample water quality.

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Robot Re-creates a Tetrapod's Moves

Cross-Curricular Connections, Q

Directions: Answer the questions below based on your teacher's instructions.

1. What background knowledge would you need to complete the specified research approach? What type of prior research experience and/or fieldwork would have been helpful?

2. What type of data would you get from this research approach and what insight might that data offer?

3. Come up with a possible hypothesis about a tetrapod's gait that could be tested via the approach. State specifically whether your hypothesis applies to modern or ancient tetrapods. What is a possible result relating to the hypothesis?

4. What gaps in knowledge would you still have following the investigation? What additional approach could help you fill in the gaps?

5. Scientists used this research approach to study the locomotion of an extinct species. What other types of research questions in other fields currently benefit or could benefit from the approach your group studied? Look up information, if needed, to give an example.

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Robot Re-creates a Tetrapod's Moves

Activity Guide for Teachers: Tracing Tracks and Guessing Gaits

Purpose: To understand how scientists can make inferences and construct explanations about animal movement by analyzing those animals' tracks.

Procedural overview: Just as the scientists in "Robot re-creates a tetrapod's moves" analyzed tracks and other data to make inferences about an ancient tetrapod's gait, students will analyze tracks created by classmates. After pairs of students make sets of tracks using varied gaits of their choice, they will trade with each other and study unfamiliar tracks. By using what they know about human range of motion, gravity, friction and balance, students will try to infer how their classmates made the unfamiliar tracks and what style of gait was used.

Approximate class time: One class period.

Supplies:

- Activity Guide for Students: Tracing Tracks and Guessing Gaits
- Lots of newspapers, newsprint or packing paper
- Clear packing tape
- Plastic bowls of water
- Paper towels
- Pencils
- Tape measures
- Cell phone timers or stopwatches
- Calculators
- Rubber bands
- Optional: Classroom computer projector to show video clip

Directions for teachers:

Have students work in pairs to make tracks on paper according to the directions for students below, ideally in locations where other students can't watch (in different hallways at school or even at home). On a separate sheet of paper, students should write down their names and information about their tracks.

Then collect the paper trackways and student information sheet, mark each pair's trackways and student information sheet with the same letter and redistribute the trackways so each pair has a new set.

Pairs should use the Activity Guide for Students to analyze the trackways to see how much can be learned about other students' gaits. Be sure to provide more newspaper so students can test their hypotheses.

You can choose to share the student information sheet with the pairs only after they have analyzed the trackways and tested their hypotheses.

Notes to teachers:

If time permits, before students begin, consider playing the video of the tetrapod robot from the article "Robot re-creates a tetrapod's moves." Remind your students that the more irregular their walks, the harder it will be for other students to analyze the gait.

Instead of using paper, students could make and study footprints in sand or soft soil outside. That approach would permit measurements of the depth of the tracks and estimates of speed based on depth and depth variations in tracks.

Students could also, or alternatively, build and then analyze the gaits of different types of walking robots. That activity ties in well with the robotic reconstruction described in the *Science News* article. Good sources for a variety of simple, inexpensive robot kits include American Science & Surplus, Home Science Tools, Educational Innovations Inc., and Scientifics Direct.

Directions for students:

As discussed in "Robot re-creates a tetrapod's moves," researchers tried to reconstruct the gait of *Orobates pabsti*, a creature that lived between 280 million and 290 million years ago, based on its fossilized skeleton and tracks. Inferences about a wide variety of prehistoric creatures, from worms to dinosaurs to hominids, have been made based on the tracks these animals left behind. And studying the tracks and gaits of living creatures can help us better understand everything from the population sizes and ranges of endangered animals to how to design prosthetic limbs to reconstructing crime scenes.

In the first part of this activity, you will work in pairs to make tracks on paper. Follow your teacher's instructions to find a place where other students from the class can't observe you.

In the second part of the activity, you will trade trackways with another pair of students. You and your partner will use what you know about human range of motion, gravity, friction and balance to analyze the trackways and try to infer how your classmates made the unfamiliar tracks and what style of gait was used.

Making tracks

1. Spread out newspaper sheets and tape them together securely to make a paper path at least 3 meters long (about 10 feet). Then flip the path over, so the tape is on the bottom, where it won't interfere with making and measuring tracks.

2. Choose a gait to use to go down the paper path. You can choose to travel either forward or backward; to walk, run, hop, skip, etc.; to walk with your feet, with your knees, on all fours, crawling like a crab, etc.; to use different shoes, socks or go barefoot. Your gait should have the same approximate speed and method for the entire path — no speeding up or slowing down, no changing style along the way. Your partner can choose the same gait as you or a unique gait.

3. Once you have decided on your gaits, use a bowl of water or wet paper towels to wet your feet and any other parts of you that will come in contact with the paper. You want to leave good prints.

4. Now make your prints. Go down the same paper path, one at a time, to make the prints. It's OK for you and your partner's trackways to overlap, but try to avoid too many cases where individual prints overlap since that will make measuring the tracks difficult.

5. Have your partner time how long it takes you to get to one end of the paper to the other.

6. Immediately after making wet tracks, trace around each track with pencil or marker to outline the tracks before the water dries.

7. Write down information about your tracks on a separate sheet of paper:

Student 1 time:
Student 1 gait (describe in as much detail as possible):

Student 2 time:
Student 2 gait (describe in as much detail as possible):

8. When you are done creating your paper trackways, roll up your paper (adding additional tape for support if necessary) and put rubber bands around it. Do not write your names or other information on your paper trackways.

9. Give the paper trackways and the student information sheet to your teacher.

Studying tracks

1. Obtain from your teacher paper trackways that were made by another pair of students.

2. Can you determine two distinct sets of tracks even if the tracks overlap? How did you figure it out?

3. Use a tape measure to find the following information about one set of tracks and record your results.

Length and width of each type or shape of print (make a note if you can distinguish footprints from handprints).

Average length and width for each type of print (if they vary in size).

Student 1 length (along the trackway) from one track until that same sort of track is repeated (how far the student traveled while going through one complete cycle of motion for that gait). If there are several cycles of a given type along the trackway, measure and record them all, then calculate the average.

Are there any other quantitative measurements you could take? If so, take those measurements and record them below.

4. What type of information might be inferred about the physical dimensions of the human from the quantitative track data collected?

Leg length or overall height could be guessed, but the guess would not be conclusive.

5. What qualitative observations can you make about the tracks? Record any observations that could be helpful in determining the gait used. Consider, for example, the shape of the prints and track and how uniform the track looks across its length.

Analyzing the shape of the print should be helpful. Is it a hand, foot or something else? Is it a full print or partial print? Uniformity of the track could provide clues to whether the gait is well-balanced.

6. Based on the quantitative and qualitative track data you collected, predict the style of gait you think the student used.

Student answers will vary, but students should generate a hypothesis based on their observations.

7. At what speed do you think the student traveled down the path? Do a quick test using a measuring tape and a timer if you need a rate to use as a reference.

A typical walking speed might be about 1.5 meters per second. If tracks look like a full shape of a shoe, this could indicate a normal to slow walking speed. If partial shoe tracks are noted, then the student may have jogged or ran.

8. Test your gait hypothesis by trying to reproduce similar tracks with your own motions. If your first hypothesized gait cannot generate a similar track, generate and test other hypotheses. Describe the gaits you try and which one best matches the track pattern. Can you reproduce the exact gait? Why or why not?

Student answers will vary. A different student will not be able to produce the exact trackway due to differences in body size.

9. Repeat steps 3 through 7 for the second set of tracks.

10. Obtain the written descriptions for how the other students actually made the tracks. How well did you do at figuring it out? What were the easiest aspects to figure out, and what were the hardest aspects?

Student answers will vary.

11. How close were you on your speed estimates? Would knowing the speed have helped you figure out the gait?

Student responses on the accuracy of speed estimates will vary. Speed of movement will depend on a person's body dimensions and how fast they choose to move with a particular gait, so it will not definitively indicate gait. However some gaits require more time to complete than others, so knowing speed might help narrow down the type of possible gait.

12. Think about the qualitative and quantitative track data that you collected. Predict how each of the following factors could change the tracks from each student's gait.

An increased range of motion of the ankle joint in humans.

Tracks might be farther apart.

A decrease in the gravitational force on Earth.

Tracks might be farther apart and tracks might not be full impressions of the body part used to make them.

An increase in the frictional force between the surface and the body part in contact with the surface.

Tracks might be closer together.

13. What have you learned about methods of analyzing tracks?

There are many qualitative and quantitative measurements that can be made on an animal trackway, but knowledge about the animal's body shape, size, skeletal and muscular structure, joint mobility, etc., is also very helpful when trying to infer an animal's movement from its trackway. Animals of the same species can also have a variety of tracks.

14. What have you learned about the scientific method in general?

While analyzing the trackways, we used the scientific method to problem solve. We were presented with an unknown trackway that we had to analyze to come up with a hypothesis about a gait that could create the given trackway. Once we came up with our possible gait hypothesis for each trackway, we tested it by performing the gait and trying to reproduce the track pattern. If we could reproduce a similar gait, we knew that the gait could have been one that created the pathway. Thorough data collection, analysis and problem solving is essentially the scientific method.

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Robot Re-creates a Tetrapod's Moves

Activity Guide for Students: Tracing Tracks and Guessing Gaits

Directions: As discussed in "Robot re-creates a tetrapod's moves," researchers tried to reconstruct the gait of *Orobates pabsti*, a creature that lived between 280 million and 290 million years ago, based on its fossilized skeleton and tracks. Inferences about a wide variety of prehistoric creatures, from worms to dinosaurs to hominids, have been made based on the tracks these animals left behind. And studying the tracks and gaits of living creatures can help us better understand everything from the population sizes and ranges of endangered animals to how to design prosthetic limbs to reconstructing crime scenes.

In the first part of this activity, you will work in pairs to make tracks on paper. Follow your teacher's instructions to find a place where other students from the class can't observe you.

In the second part of the activity, you will trade trackways with another pair of students. You and your partner will use what you know about human range of motion, gravity, friction and balance to analyze the trackways and try to infer how your classmates made the unfamiliar tracks and what style of gait was used.

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2. Choose a gait to use to go down the paper path. You can choose to travel either forward or backward; to walk, run, hop, skip, etc.; to walk with your feet, with your knees, on all fours, crawling like a crab, etc.; to use different shoes, socks or go barefoot. Your gait should have the same approximate speed and method for the entire path — no speeding up or slowing down, no changing style along the way. Your partner can choose the same gait as you or a unique gait.

3. Once you have decided on your gaits, use a bowl of water or wet paper towels to wet your feet and any other parts of you that will come in contact with the paper. You want to leave good prints.

4. Now make your prints. Go down the same paper path, one at a time, to make the prints. It's OK for you and your partner's trackways to overlap, but try to avoid too many cases where individual prints overlap since that will make measuring the tracks difficult.

5. Have your partner time how long it takes you to get to one end of the paper to the other.

6. Immediately after making wet tracks, trace around each track with pencil or marker to outline the tracks before the water dries.

7. Write down information about your tracks on a separate sheet of paper:

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8. When you are done creating your paper trackways, roll up your paper (adding additional tape for support if necessary) and put rubber bands around it. Do not write your names or other information on your paper trackways.

9. Give the paper trackways and the student information sheet to your teacher.

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2. Can you determine two distinct sets of tracks even if the tracks overlap? How did you figure it out?

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Are there any other quantitative measurements you could take? If so, take those measurements and record them below.

4. What type of information might be inferred about the physical dimensions of the human from the quantitative track data collected?

5. What qualitative observations can you make about the tracks? Record any observations that could be helpful in determining the gait used. Consider, for example, the shape of the prints and track and how uniform the track looks across its length.

6. Based on the quantitative and qualitative track data you collected, predict the style of gait you think the student used.

7. At what speed do you think the student traveled down the path? Do a quick test using a measuring tape and a timer if you need a rate to use as a reference.

8. Test your gait hypothesis by trying to reproduce similar tracks with your own motions. If your first hypothesized gait cannot generate a similar track, generate and test other hypotheses. Describe the gaits you try and which one best matches the track pattern. Can you reproduce the exact gait? Why or why not?

9. Repeat steps 3 through 7 for the second set of tracks.

10. Obtain the written descriptions for how the other students actually made the tracks. How well did you do at figuring it out? What were the easiest aspects to figure out, and what were the hardest aspects?

11. How close were you on your speed estimates? Would knowing the speed have helped you figure out the gait?

12. Think about the qualitative and quantitative track data that you collected. Predict how each of the following factors could change the tracks from each student's gait.

An increased range of motion of the ankle joint in humans.

A decrease in the gravitational force on Earth.

An increase in the frictional force between the surface and the body part in contact with the surface.

13. What have you learned about methods of analyzing tracks?

14. What have you learned about the scientific method in general?

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Related Articles

Science News:

"Robot fish shows how the deepest vertebrate in the sea takes the pressure," Readability: 9.3

"Here's how geckos (almost) walk on water," Readability: 12.0

Science News for Students:

"*T. rex* may not have been able to run — but it was still pretty fast," Readability: 6.2

"This robotic jellyfish is a climate spy," Readability: 8.0

"Four-legged robot might show how ancient creature walked," Readability: 8.5