NanoLeap

Investigating Static Forces in Nature: The Mystery of the Gecko
Lesson 5: What Types of Forces Can Hold Objects Together?
Activity: What Sticks?

Student Learning Objectives:

- Explain the properties of an adhesive
- Describe what happens when the surface of an object is brought into contact with the surface of another object
- Characterize different methods of adhesion
- Evaluate applicability of different methods to explain gecko adhesion

Note: By the end of this lesson, students should have ruled out all mechanical methods of adhesion, leaving intermolecular forces to be explored in more detail in the subsequent lessons.

At a Glance for Teachers:

- Exploration of different materials and their ability to adhere in stations
- Teacher demonstration with magnets
- Exploration of variables that affect adhesion
- Homework: Write a procedure to test the variables of two adhesives
- Read some research about different adhesion methods
- Complete an Adhesion Methods Debrief Chart *(Adhesion Methods Student Handout*)

Note: Some questions in the Student Journal are underlined as formative assessment checkpoints for you to check students' understanding of lesson objectives.

Estimated Time: 90–100 Minutes

Vocabulary: Adhesion, Adhesive
Refer to the end of this Teacher Guide for definitions.

Materials:

- PowerPoint for Lesson 5

- Student Journal for Lesson 5
- Copies of *Adhesion Methods Student Handout* (one complete packet per student group)
- Computer with LCD and overhead projector and magnets for teacher demonstration
- Set up materials in stations, as outlined in the table below, for the students to investigate:

Station	Materials	Adhesion Methods Examples
1	Magnets, Paperclips, Plastic Transparency	Friction, Magnetic
2	Suction Cups, Plastic Transparency	Air Pressure (Suction)
3	Fur or Wool, Balloon, and/or Styrofoam™ Plate Paper Pieces and Plastic Transparency	Intermolecular Static Electricity
4	Beaker of Water, Paper Towel, Plastic Transparency	Capillary Wet Adhesion
5	Washers, Velcro®, Plastic Transparency	Micro-Interlocking: Velcro
6	Transparent Tape, Plastic Transparency	Intermolecular: Electrical
Additional Stations		
7	Lego™, magnet	Mechanical Interlocking, Friction
8	water, hand, suction cups, table top	Capillary Wet Adhesion, Air Pressure
9	Play-doh™, clay, plastic lid (with raised surface-like lettering)	Capillary Wet Adhesion, Friction

Slide # Student Journal Page #	*Teacher Background Information and Pedagogy* **"Teacher Script"**
Slide 1 Title	*1) This is a guided exploration activity. It is designed so that students will have an opportunity to determine many different ways for two objects to "stick" together. As you set up this activity, provide the materials in different stations and read the statement on Slide 2 out loud for students to begin their exploration.*
Slide 2	*2) Introduce the activity:* **"You will be working at several stations using an assortment of materials to test and record some ways that objects adhere to the plastic transparency."** *Explain to students that they will only be allowed 3–5 minutes per station to record their observations.*
Slide 3–4 Student Journal Page: 5–1 5–2 5–3 5–4	*3) Explain that for each station there is a recommended procedure, but they should also explore on their own. Instruct students to record their findings for each station in the table of their journal. Emphasize that during at least one station they should describe the factors or variables that affect how well the objects stick.*
Slide 3–4 Teacher Demonstration	*4) Once students complete the "what sticks" activity, have them brainstorm other examples of objects that adhere together in similar ways as the materials in the activity. Record student responses on the board.* **"What are some methods that caused the things to stick together?"** *Students' answers from the pilot test included: suction, static electricity, magnetic force, interlocking, and water adhesion.* <u>*Dominant Forces:*</u> *5) Place two magnets on an overhead projector about 15 cm. apart. Ask students to describe the forces at work on each magnet and the resulting lack of motion. Slowly move one magnet closer to the second magnet. As the distance decreases, ask the students what force they were able to infer. (Magnetic force. Friction oppose the attractive magnetic force. As one magnet moves closer to the other, the magnetic force becomes dominant over friction.)*

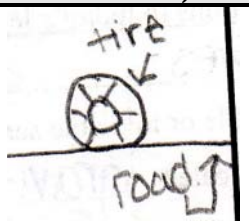
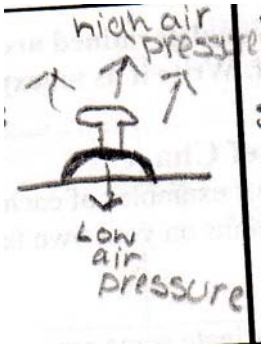
Slide 5 Student Journal Pages: 5–4	*6) This exercise helps students begin thinking about the many variables that affect adhesion. Once they have provided a list of variables, ask the students to indicate which are testable and which are not. Variables mentioned in the pilot test included the amount of wetness, temperature, mass of the objects, whether the objects were dirty or clean, and the amount of surface area or the amount of force applied.* **1. "Choose one pair of objects that stuck together during your exploration. Then, in your journal, describe the factors or variables that affect how well those two objects stick together."** **2. "Describe an adhesive in your own words. What are the properties that make them work?"** **3. "Which factors or variables are testable and which are not?"**
Slide 6 Student Journal Page: 5–4	*7)* Describe how you made observations in today's lesson. a. What senses/tools did you use? *seeing/feeling* b. What observations were at the visible scale? *answers will vary* c. What dominant force did you observe? *student answers may include: gravity, friction, magnetism etc.* d. What are other forces that you observed that may be at the invisible scale? *student answers may include: magnetism, static electricity, wet capillary adhesion, etc.*
Student Journal Page: 5–4	**"Homework: Based on the factors that you determined are testable, write a plan to determine how a factor could be tested. Write it as an experimental procedure."** *Explain to students that a good procedure clearly communicates a step-by-step process for completing the experiment. Included in the procedure are materials, how long you expect the experiment to take, and any other information that is important to completing the experiment. The plan should be detailed enough for another investigator to repeat the experiment just as you did originally[1]. Pilot teachers felt this was a good activity. It made students think for themselves and provided good practice in writing procedures.*
Slide 7 Student Journal Pages: 5–5	*8) Referring to the Adhesion Methods Debrief Chart, prompt students by saying:* **"From the information you gained in your experiment, complete columns two through four in the chart."** *Once students have categorized the methods, have them write down what they know about each one. A key has been provided for the teacher at the end of this Teacher Guide. It is not intended to be shared with the students at this time.*

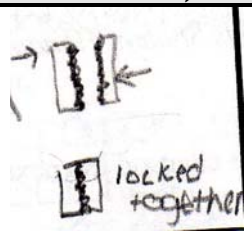
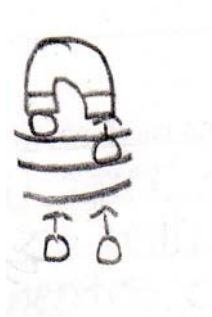
[1] Adapted from: Ramig, J.E., Bailer, J., & Ramsey, J. M. (1995). *Teaching science process skills*. Good Apple: Torrance, CA.

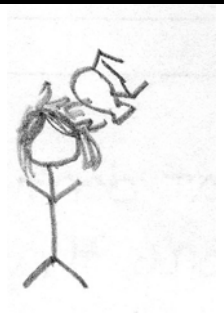
5–6 5–7	*Encourage students to write the definitions in their own words.* *9) Divide the class into seven groups (one for each method). After allowing time for students to complete columns 2-4 of the chart, resume the class discussion.* **"Let's return to the gecko problem. Do you think that any of the materials that you explored are similar to the gecko's adhesion? Over the years, scientists have hypothesized many different possible methods for gecko adhesion."** **"Each of you will be assigned to one of seven teams for the purpose of reading some research findings from scientists who have studied different adhesion methods of geckos. You will learn from their research and determine the best hypothesis of what is happening with the gecko's foot. Each team will receive a complete packet that contains the possible methods and some findings. Each person should take notes about what they read. Be prepared to report to the class what you have found. During each presentation, you will take notes while listening to the other groups' presentations in your journal, the Adhesion Methods Debrief Chart for Slide 7."** *10) To complete the last two columns in the Adhesion Methods Debrief Chart**:* • *Distribute the Adhesion Methods handout (one page/method per group).* • *Give each group one method so that they can concentrate on that particular method.* • *Prompt students to take notes in their journal on how the method works, how it might apply to the gecko, and any research that may have been done that might relate to the gecko.* • *Debrief each of the methods as a whole class discussion.* • *Debriefing should be completed by projecting each group's handout onto a chalk board or white board and recording the students' responses. Representatives from each method should present their work. The rest of the class should record these findings in their journal (pages 5-3 and 5-4) and discuss anything that is not clear in the presentation.* *<u>Note to Teacher: There is no fundamental difference between capillary wet adhesion and the adhesion between tape and a surface. In both cases there are intermolecular forces between some substance and the surface. In one case it is water, in the other it is polymer applied to the tape. The distinction to be made here is that some remnants of water would be left behind after the two surfaces are detached for capillary wet adhesion. Tape may leave a residue whereas the gecko does not, but the example of tape should move students toward a better understanding of what is happening with the gecko.</u>* *11) Tell students to refer back to these notes in future lessons.*

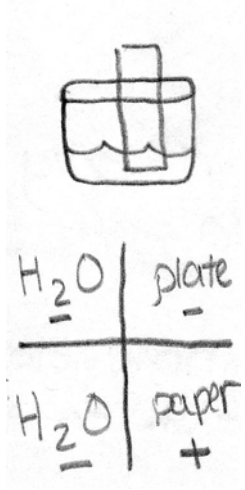
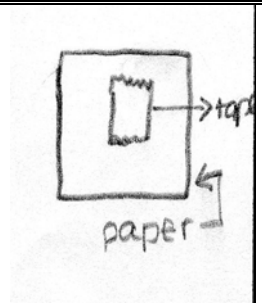
	** We recommend that this chart be developed on chart paper for each class so that it can be referred to in subsequent lessons.**
Slide 8	*1) As a discussion, ask students to respond to the "Making Connections" questions on Slide 8.* **"Let's recap what we learned in this lesson:** **1. Describe one or two ideas that you learned during this lesson.** **2. How do things stick together?** **3. Which of these ways are likely to be used by the gecko to stick to a ceiling?** **4. What should we explore next?"** **"In the next lesson, we will explore how much force is needed to make an object stick to a ceiling as well as the amount of force that is acting between two objects."**
Slide 9	*13) The pilot-test teachers highly recommend using this flow chart at the end and/or beginning of each lesson. The end of each lesson contains this flow chart that provides an opportunity to show students the "big picture" and where they are in the lesson sequence. The following color code is used:* *Yellow: Past Lessons* *Blue: Current Lesson* *Green: Next Lesson* *White: Future Lessons*

Appendix A: Answer Key for Adhesion Methods Debrief Chart

Method	Definition	Drawing That Describes the Method (From Field Test Student)	Examples from Experiment (Slide 7)	Is this method a possible answer to the gecko mystery? (Yes or No)	Why or Why Not?
Mechanical Force: Friction	Friction is the force that opposes the lateral motion of two surfaces that are in contact.		paper clip and transparency magnet on transparency	No	While there is friction between the gecko's foot and the surface, it only permits the gecko to move parallel to the surface.
Mechanical Force: Suction	Suction is the creation of a partial vacuum (region of low pressure). A suction cup is a device made of either plastic or rubber that sticks to smooth surfaces.		suction cup on transparency	No	Gecko force experiments indicate that the same force measurements have occurred when tested in a vacuum as in regular air. During field tests students said that air is key for suction to work and geckos can climb in a "vacuum room."

Method	Definition	Drawing That Describes the Method (From Field Test Student)	Examples from Experiment (Slide 7)	Is this method a possible answer to the gecko mystery? (Yes or No)	Why or Why Not?
Mechanical Force: Micro-interlocking	Two materials may be mechanically interlocked. At the macroscopic scale, examples include: a zipper, sewing two pieces of cloth with a thread, and two pieces of Velcro® that are attached.		Velcro and transparency	No	No entanglement has been observed. In fact, force measurements have been the same amount per unit area for different opposing materials. During field tests, students stated that there were no hooks on the geckos foot to attach itself to an object.
Intermolecular Force: Magnetic	A magnet is an object with a magnetic field. A "hard" magnet is one which stays magnetized for a long time. A "soft" magnet is one which loses its magnetic properties. Opposite poles of magnets attract.		magnet with paperclip	No	Gecko sticks on non-magnetic surfaces (e.g., glass, wood, concrete). During field tests, students mentioned that geckos are not made of metal or cannot create a magnetic field.

Method	Definition	Drawing That Describes the Method (From Field Test Student)	Examples from Experiment (Slide 7)	Is this method a possible answer to the gecko mystery? (Yes or No)	Why or Why Not?
Intermolecular Force: Static Electricity	Static electricity involves the buildup of charge in objects due to contact between mostly nonconductive surfaces. These charges are generally built up through the flow of electrons from one object to another. These charges then remain in the object until a force is exerted that causes the charges to balance (e.g., the familiar phenomenon of a static "shock" is caused by the neutralization of charge built up in the body from contact with nonconductive surfaces.)		fur and balloon fur and transparency	No	The adhesion force is independent of the types of opposing materials that the gecko is on. The gecko adheres equally while in clean air or heavily ionized air. During the field test students noted that the gecko could stick to neutral surfaces.

Method	Definition	Drawing That Describes the Method (From Field Test Student)	Examples from Experiment (Slide 7)	Is this method a possible answer to the gecko mystery? (Yes or No)	Why or Why Not?
Intermolecular Force: Electrical Capillary Wet Adhesion	Water molecules are not only attracted to each other, but to any molecule with positive or negative charges. When you place paper from a straw partially into a glass of water, the water will "climb" up the fibers of the straw paper because the water molecules are attracted to the cellulose fibers in the straw paper.		beaker of water, paper towel, and transparency	No	Observations made with geckos indicate that there is no wet trail left behind when geckos walk on a surface. Skin glands are not present on gecko feet—the foot does not have a way to secrete any substance. During the field test students noted that the gecko can stick to both wet and dry surfaces.
Intermolecular Force: Electrical (Tape)	Transparent tape has a rubbery composition that at the molecular level has properties similar to a liquid. The tape makes intimate contact with		transparent tape and transparency	Possibly	For this method to be a possibility, each gecko seta must have a composition similar to the rubbery composition of the tape. This would then allow the seta to make

Method	Definition	Drawing That Describes the Method (From Field Test Student)	Examples from Experiment (Slide 7)	Is this method a possible answer to the gecko mystery? (Yes or No)	Why or Why Not?
	the surface so that more intermolecular electrical attractions occur to cause adhesion.				intimate contact with the opposing surface. Students should have observed in Lesson 4 that the spatulas do not have a liquid or sticky composition. During field tests, students mention that "there is no adhesive stuff on a gecko's foot." Explanation for teacher: The forces, however, are different. The gecko is an induced-dipole (van der Waals, which are weak and temporary) interaction; whereas, the transparent tape is a dipole-dipole interaction.

Note to Teacher:

Intermolecular forces **are electromagnetic forces between molecules. These forces are much weaker than** intramolecular forces **(such as covalent bonds, ionic bonds, and metallic bonds). The following are examples of intermolecular forces from strongest to weakest: Hydrogen Bonds (Capillary Wet Adhesion), Dipole-Dipole Interactions (Hydrochloric acid), Momentary Dipole Interactions (van der Waals).**

Appendix B: NanoLeap Physical Science Vocabulary for Lesson 5

Adhesion

1. The attraction exerted between the surfaces of objects. Can be either mechanical (e.g., suction, micro-interlocking, friction) or intermolecular (e.g., electrical and magnetic)
2. Objects in contact: steady or firm attachment of objects

Adhesive

A substance that helps objects stick together