NanoLeap

Investigating Static Forces in Nature: The Mystery of the Gecko
Lesson 8: How Can a Gecko Walk on a Ceiling?
Evaluate

Student Learning Objectives:

- Describe the attractive forces between and within molecules that cause the gecko to adhere to a vertical surface
- Describe how a large number of small forces (van der Waals interactions) at the nanoscale level can add up to macroscopic forces
- Describe how a gecko can adhere to a ceiling by drawing on learning experiences throughout module

At a Glance for Teachers:

- Compare transparent tape and gecko adhesion
- Explore positive and negative charges with a computer interactive simulation
    - Positive and negative charges (charge simulator and hot spots)
    - Investigate weak forces
- Interpret diagrams showing atoms and their charges
- View *Sticky Subjects* and *Nano in Nature* video and summarize research findings
- Complete final essay assessment using the Peer Review Scoring Guide

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

Estimated Time: 90 Minutes for Lesson 8; 75 Minutes for full Essay Assessment, 45 minutes without peer review

Vocabulary: Atom, Electron, Electron Cloud, Nanotube, Negatively Charged, Nucleus, Positively Charged, Proton
Refer to the end of this Teacher Guide for definitions.

Materials:

- PowerPoint for Lesson 8
- Student Journals for Lesson 8
- Computers with Internet access for student groups
- Computer with LCD or overhead projector

Multimedia Resources:

- *Nano in Nature* video located at: http://www7.nationalgeographic.com/ngm/0606/feature4/multimedia.html
- *Sticky Subject:* ScienCentral "Animal Oddities" at: http://www.youtube.com/watch?v=gB68Eb1KLa8

For Essay Assessment: Demonstrate Your Understanding

- Completed Student Journal sheets from the entire module
- Explanation of Essay Assessment: Demonstrate Your Understanding (Note: These are the last two pages of the Student Journal from Lesson 8)
- Copies of Peer Review Scoring Guide (2 per student); Handouts to be made for students located in the Teacher Guide
- For the instructor: Anchor Papers for Essay Assessment (See Appendix A of this Teacher Guide)

Advanced Preparation: Load and test the Web sites at least one day in advance of the lesson

- *Ion Engine Hotspots Game:* http://dawn.jpl.nasa.gov/mission/ion_engine_interactive/lev2/index.html
- *Charge Simulator:* http://dawn.jpl.nasa.gov/mission/ion_engine_interactive/lev1/index.html
- *Balloons and Static Electricity:* http://phet.colorado.edu/simulations/index.php?cat=Electricity_Magnets_and_Circuits

<u>Slide #</u> **Student Journal Page #**	*<u>Teacher Background Information and Pedagogy</u>* **“Teacher Script”**
Slide 1 Title	1) *Remind students about the concept of static electricity by recalling what happens when a Styrofoam® plate or balloon is rubbed with fur and can stick to a surface.* *Optional: Demonstrate this for the class. Then, hit the charged object (balloon or plate) on a desk to return it to neutral.* *Optional Computer Simulation available at:* *http://phet.colorado.edu/simulations/index.php?cat=Electricity_Magnets_and_Circuits* *Click on “Balloons and Static Electricity”*
Slide 2 Student Journal Page: 8–1	**“Let’s take a look at what is happening at the end of the gecko seta. Recall the activities that you have done within this module. How do the spatula shaped tips of the setae come into close contact with the surface?”** *The image on the slide shows the spatula-shaped tips at the end of a single gecko seta. Each spatula is about 100 nanometers thick.* 2) *Show the model from Lesson 7. Students should recall that the spatula-shaped tips come into very close contact with the surface to which it is adhering by fitting into the nooks and crannies of the seemingly smooth surface. This allows for a large amount of surface contact to be made per total surface area.* *Note: You may want to review the progression of slides that depict the gecko foot structure close up from Lesson 4 (slide 6).*
Slide 3 Student Journal Page: 8–1	**“How is the gecko seta similar to the transparent tape example? How is the gecko seta different than transparent tape?”** *Gecko adhesion is similar to transparent tape in that both comply to their respective surfaces. Some students in the field test stated that both are “squishy” or like an “adhesive liquid.” It is different in that tape will lose its stickiness and leaves a residue, seta do not. In fact, setae are self cleaning.* **“The image on the top of this slide is an artist’s sketch of the spatula-shaped tips in contact with the surface (like a smooth piece of glass). How does this relate to the model that we developed with the spatulas and blocks in lesson seven?”** *It shows how the spatula shaped tips fit in nooks and crannies.* **“Let’s take a closer look at the molecular level to examine what is happening between the gecko seta and the surface.”**

	3) Explain that the image at the bottom of this slide shows transparent tape on a black lab table highlighted with white out similar to what they did in a previous lesson. ***Teacher Information****: Both transparent tape and gecko adhesion make use of intermolecular forces. The transparent tape must have the characteristics of a liquid. The gecko seta has many spatula-shaped tips that can get into the nooks and crannies of a surface. Both are compliant with the opposing surface as shown in the diagram at right.*
Slide 4	**"How does the kind of charge on a particle affect the deflection of a positively charged particle?"** *4) Have students play the "Charge Simulator" or "Hot Spots Game" (about 15 minutes) at:* *http://dawn.jpl.nasa.gov/mission/ion_engine_interactive/lev2/index.html* *http://dawn.jpl.nasa.gov/mission/ion_engine_interactive/lev1/index.html*
Slide 5 Student Journal Page: 8–1	*5) Once students have played for several minutes, give them a chance to play the games and answer the questions for slide 5 in their journals. "Players and soccer balls" are used in the Hot Spots game, "dots" are used for Charge Simulator. The questions below can be used for either.* **1. "What is the effect of placing a <u>negatively</u> charged player (red dot) close to the path of the positively charged soccer ball? (blue dot)"** *Students should indicate that the positive soccer ball (blue dot) is attracted to the negatively charged player (red dot).* **2. "What is the effect of placing a <u>positively</u> charged player (blue dot) close to the path of the positively charged soccer ball? (blue dot)"** *Students should indicate that the positive soccer ball (blue dot) is repelled by the positively charged player (blue dot).* **3. "What are your thoughts about the gecko seta surface and the ceiling surface as they relate to charges?"** *Students might indicate that there are charged particles on the surfaces. Students might think that one surface is positive and the other is negative causing an attraction.*
Slide 6-7 Student Journal Page: 8–2	*6) Allow the students to observe and record their descriptions in their journals. Lead them to an understanding that the spheres represent atoms and the different groupings of spheres represent molecules. Explain that atoms and molecules are attracted to each other (positives attract to negatives and neutral particles) and that this attraction is an* ***electrical force,*** *which sometimes causes them to stick together. Explain that this animation represents the weakest interaction, which is temporary between atoms or molecules.*

	"In your journal are illustrations of weak attractions between molecules as shown in the animation. Identify the illustration that shows:" 1. The attraction between two polar molecules. (A) 2. The attraction between two non-polar molecules. (C) 3. The attraction between a polar and non-polar molecule. (B) *7) Show the animation on slide 6 "Weak Attractions."* **"View the animation. The dashed lines represent an attraction."** **4. "What makes you think that these are weak?"** *Most students will indicate that these are weak forces because they are easily broken.* **5. "Are these permanent or temporary attractions? How long do they last?"** *Temporary* **because** *the molecules are in constant motion, and they tend to move away from each other fairly quickly.*
Slide 8 Student Journal Page: 8–3	**"What is the overall charge of each atom in this diagram?"** *Neutral* **"In the diagram, what side of the atom is more negative?"** *Left* **"Not including the nucleus, what side of the atom is less negative?"** *Right* **"Would the two atoms attract or repel? Explain your answer"** *Guide students to realize that the left side of image 8.9 is more negative than the right side of 8.8. This results in an attraction.* **"Would the two atoms attract or repel?"** *Students might suggest that they will have an attraction.*
Slide 9	**"What is the overall charge of each atom in this diagram?"** *Neutral* **"What happens when you put two atoms like this side by side?"**

	Allow students to speculate. **"Would the two atoms attract or repel?"** *Ask them to justify their answer.*
Slide 10 Student Journal Page: 8–3	**"In this slide, we will show what is happening between the surface and a single seta. Image 8.12 shows the seta on a probe surface. The red lines show a magnified view of each surface. Image 8.13 shows the surface of a seta with spatula-shaped tips, and image 8.14 shows a drawing of the probe surface. Image 8.15 shows what might be happening between one atom on the probe surface and one atom on the spatula."** 8) *Draw student's attention to image 8.15. Note that the distribution of the electrons there are more on the left of each atom, causing an attractive force. Explain to students that these forces are very weak and temporary.* **"We found in lesson six that on average a gecko would need to have an adhesive force of about 2.2 Newtons in order to adhere to a surface. Based on an average single seta force of 180 microNewtons (or 0.00018 Newtons) and if a gecko has approximately one million setae, how much potential force is available to the gecko?"** *0.00018 Newtons times 1 million setae = 180 potential Newtons for the gecko to adhere to a ceiling if all setae were used equally.* *Note: The researchers found that geckos sustain an average of 43.4 N of clinging force with 227.1 mm^2 pad area. (see reference in footnote below)* **"What we have found is that gravity plays an insignificant role at the nanoscale level. Instead the gecko has these small intermolecular forces between each seta and the surface it is adhering to, resulting in a billion points of contact, which, when added up, is enough force to hold an entire gecko onto a vertical surface."** ***Teacher Background:*** *A dipole is a pair of electric charges or magnetic poles of equal magnitude but opposite polarity (opposite electronic charges), separated by some, usually small, distance.* *The following is a quote about the type of force that scientists think is at work between the gecko setae and a surface:* *Van der Waals attractions occur when objects are close together. There is a fluctuation in the electron distribution (electrons are slightly correlated) resulting in a very weak attractive force. Van der Waals may be significant when there is a large area of contact between objects that are close together...calculations of the complete van der Waals force between two complex macro-scale objects are simply too complicated to perform, and therefore adhesion force measurements*

	on...individual setae are necessary for verifying the van der Waals mechanism.[1] *Electrons are always moving around in an electron cloud. In general, the more room that electrons have, the more they can move. Image 8.15 depicts a momentary fluctuation creating a temporary dipole in a molecule that is usually non-polar. As this happens, electrons are pushed away in some places and toward other places. This momentary dipole induces another dipole to be created in a nearby molecule resulting in an attractive interaction. These weak interactions, known as induced-dipole/induced-dipole interactions, are always attractive and can occur between two particles in order to lower the total energy in a system. However, the interactions add up when large areas are involved. The PhET balloon and static electricity simulation shows momentary polarization of the charges on the wall when the charged balloon is brought near; although not a neutral-neutral interaction, it does show induced polarization.*
Slides 11–13 Student Journal Page: 8–4	*9) Direct students to view the animations on slides 11 and 12.* *For slide 12, prompt students to consider the following:* **“Which molecule has the most contact with the green molecule? Explain your answer.”** *Molecule one has many more surface contact than molecule two because of its shape.* **“Explain how shape affects the number of attractions between the object and the surface.”** *If the shape is more compliant (can fit into nooks and crannies) with the surface, then more attractions are possible.* **“Which molecule acts most like the gecko seta? Explain your answer”** *Molecule one fits into the nooks and crannies of the green (surface) molecule. The gecko setae can form intimate contact with most any surface resulting in the many intermolecular electric attractions required to adhere to a surface.*
Slide 14	*10) Students should work in small groups to answer these questions. Note there is an additional question in the Student Journal that is not included here.* **“Use the questions on this slide to develop your answer for the gecko adhesion problem. In the essay assessment, you will be asked to describe these forces in detail.”** **“Describe the number and strength of forces involved in gecko adhesion.”** *There are a large number of very small forces at work in gecko adhesion.* **“What part of the atom moves in response to momentary charge rearrangements?”**

[1] Autumn, K., Liang, Y. A., Hsieh, S. T., Zesch, W., Chan, W. P., Kenny, T. W., Fearing, R., & Full, R. J. (2000). Adhesive force of a single gecko foot-hair. *Nature*, 405, 681-684.

	The electrons **"Describe this interaction between the electrons of each atom. Describe the overall charge and how long the attraction lasts."** *While the atoms may be neutral, the electrons in their orbits were temporarily attracted or repelled.*
Slide 15	**"So what? How does this help us in our everyday world? If scientists know more about this natural adhesive, they can potentially develop an artificial adhesive. What could an artificial adhesive be used for that has the following characteristics?"** **An artificial adhesive that:** • **Has all of the adhesive ability of a gecko** • **Lasts forever** • **Leaves no residue behind on the surface** *11) Play the Sticky Subject: Sciencentral "animal oddities" a 42 second video found at: http://www.youtube.com/watch?v=gB68Eb1KLa8* *12) Play the "Nano in Nature" video clip found at:http://www7.nationalgeographic.com/ngm/0606/feature4/multimedia.html* *13) Review the bulleted list of research findings on the slide. Note that it is still not clear how the gecko can walk through dirt, and then self-clean so quickly. Explain that this represents another question that can be explored by students in the future.* "**Brainstorm a list of potential applications for an artificial adhesive**." *14) Encourage students to be creative in their thinking. Students may want to think about all the ways duct tape is used. Some students have really used duct tape in really useful ways in art and technical shop class (e.g., wallets made entirely from duct tape, back packs reinforced with duct tape).* *Potential applications include: space tape, improved "ouchless" bandages, internal surgical bandages, moving microchips or fibers without scratching them, self cleaning adhesive that works anywhere, climbing athletic shoes).*

Slide 16	*15) 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*
Essay Assessment Writing Prompt in Student Journal Page: 8–5	**"In this summative performance assessment, you will demonstrate your learning in this module by responding to the following writing prompt.** **Explain how the gecko can adhere to a ceiling. Your written explanation should include the following:** • **Describe (with words and/or labeled drawings) the surface-to-surface interactions between gecko "setae" and a ceiling. Be sure to address the characteristics of both the setae and the surface. Include the shape, number, and size of setae in contact with the surface.** • **Describe the variables affecting adhesion: the surface area, the surface contact, and the type of surface.** • **Explain how a lot of tiny adhesive forces overcome the force of gravity.** • **Describe the electrical forces and their role in gecko adhesion (i.e., interactions of charged particles between atoms of the spatula and the ceiling surface)."** *1) Students will draft their written responses as homework and then participate in a peer-review activity during class time. Incorporating peer review transforms the "test" into a writing-to-learn opportunity that engages students in critical thinking with a more in-depth exploration of the content. Furthermore, feedback received through the peer-review process will help students to refine their writing before the final essays are submitted. Through this process, students will also become very familiar with the scoring rubric and expectations for the writing, thereby encouraging them take responsibility for evaluating their own work. Subsequently, the teacher's paper load in this module can be minimized; you may only need to intervene and evaluate the writing when there is a large discrepancy among peer reviews.*
Essay Assessment Introduction Student Journal Page: 8–6	*2) Instruct students to turn to the Essay Assessment: Demonstrate Your Understanding section of their Lesson 8 Student Journal; this should be the last two pages (8-5 and 8-6). Explain to students that they will show what they've learned throughout this module by responding to the writing prompt.* *3) Review the prompt to ensure students understand. The bulleted list provides scaffolding to assist students in fully addressing the prompt. Student responses may include diagrams or images; however, such visuals should be used to reinforce the written explanations not replace them. Each written response should not exceed one-typed page (or one-handwritten page front/back).* *4) Invite students to refer to their journals to help them plan their responses. While the assessment is "Open Journal/Notes,"*

	emphasize to students that their essay responses should not simply repeat journal responses. The journals are intended to help students recall their learning experience. The writing should be in students' own words and reflect a sophisticated understanding of the content. 5) *Review the instructional rubric that will be used to evaluate the written responses. The more familiar students are with the expectations of the assessment, the more responsibility they can assume for their own work.*
Drafting the Essay	6) *Instruct students to refer to the rubric as they draft their written responses.* 7) *Allow one class period for students to respond to the prompts. They may finish the essays for homework.*
Peer Review	8) *Collect students' essays.* 9) *Devote half of a class period to conduct a peer review using the Peer Review Scoring Guides. Distribute two copies of the Peer Review Scoring Guide to each student.* 10) *Explain to students that the Peer Review Scoring Guide is based on the instructional rubric, the tool the teacher will use to evaluate their final essays. Therefore, the Scoring Guide will help students give feedback to their classmates. Honest and thorough feedback will enable their classmates to revise their writing before the final assessment is submitted to the teacher.* 11) *Redistribute the essays to the class. Ensure that everyone has a different paper, one other than their own.* **Teacher Tip** You may feel that your students would respond more favorably to an anonymous peer-review process. Assign a special ID code to each student—be sure to keep the master list. Authors will write this ID instead of their name on their paper. Then, ask peer reviews to write both the author's and their own ID on the Scoring Guide. Remind them to label the IDs as either "Author" or "Peer Reviewer" so that the evaluations may be matched to the correct paper at the end of the peer-review process. 12) *Students should write a "*" in the upper corner of each paper they review. This mark will help keep track of how many times a paper has been peer reviewed; each paper should be reviewed twice.* 13) *Remind students to write both the author's and the peer reviewer's name on the Scoring Guide so that the evaluations may be matched to the correct paper at the end of the peer-review process.* 14) *Once students have reviewed one paper, they should return the paper to a designated bin and select another paper to review. Instruct students to turn in the completed Peer Review Scoring Guide to the teacher. The teacher should then glance*

	at each scoring to ensure that the proper feedback was included and then immediately return the scoring guide to the author. Note: Once a paper has been reviewed twice, as indicated by two "" at the top of the paper, it should not be returned to the bin to ensure it is not selected/reviewed again. Instead, return it to the author.* *15) Allow some class time for students to review the feedback. If students feel there are significant discrepancies (more than a two point difference in scores between two peer reviews), it will be necessary for you to intervene and provide some clarifications. Determine how you would like students to request your intervention. (e.g., If class time permits, conduct one-on-one conferences with students as needed, or ask students to resubmit their papers and accompanying peer review rubrics for your review).*
Refining and Evaluating the Final Essays	*16) Encourage students to revise and polish their writing according to the feedback they received. Assign a due date for completing their final draft.* *17) On the due date, collect the rough draft, the two Peer Review Scoring Guides, and final draft from each student.* *18) Refer to the Anchor Papers for Essay Assessment to assist in evaluating the final essays. (Available in the Appendix A section of this guide). Below is a copy of the instructional rubric.*

Instructional Rubric for Essay Assessment

Criteria	Advanced (4)	Proficient (3)	Partially Proficient (2)	Novice (1)
Writing Style and Mechanics	• **Concise, clear, and engaging explanations** with **flawless** spelling, punctuation, and grammar.	• **Concise and clear** explanations with **minor errors** that do not interfere with communication.	• **Appropriate writing** format. • Writer does **not appear to have carefully proofread**.	• **Demonstrates little or no attention** to the writing format. • Has great difficulty communicating.
Understanding of Content	• **Explanations** are complete* and **detailed, demonstrating a sophisticated** understanding of surface-to-surface interactions and forces affecting adhesion. • Writes in **own words** using **common and scientific language.** *Responses include answers to all four bullet points in the prompt.	• **Explanations** are **complete*** demonstrating an understanding of surface-to-surface interactions and forces affecting adhesion. • **No clear inaccuracies** or misconceptions. • Mostly writes in **own words** using **common and scientific language.** *Responses include answers to all four bullet points in the prompt.	• **Explanations demonstrate a basic** understanding of surface-to-surface interactions and forces affecting adhesion. • **May contain inaccurate** or **incomplete** information. • Writes using **scientific language** only, **not always writing in own words**.	• Explanations are **missing important information.** • **Does not demonstrate a basic understanding** of surface interactions and forces affecting adhesion and/or **contains inaccuracies**. • Writing is **not in own words**.

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Appendix A: Anchor Papers for Summative Essay Assessment

Purpose:
The anchor papers can assist you in using the rubric to score students' culminating essays. Please refer to the rubric as you read through the various anchor papers.

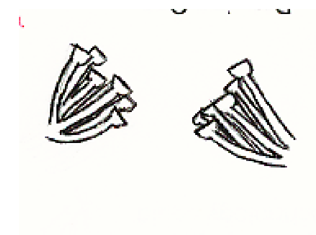
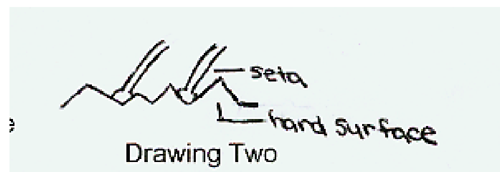
Writing Prompt:
Explain how the gecko can adhere to a ceiling. Your written explanation should include the following:

- Describe (with words and labeled drawings) the surface-to-surface interactions between gecko "setae" and a ceiling. Be sure to address the characteristics of both the setae and the surface. Include the shape, number, and size of setae in contact with the surface.
- Describe the variables affecting adhesion: the surface area, the surface contact, and the type of surface.
- Explain how a lot of tiny adhesive forces overcome the force of gravity.
- Describe the electrical forces and their role in gecko adhesion (i.e., interactions of charged particles between atoms of the spatula and the ceiling surface).

Rubric (for Content only)

Understanding of Content	• **Explanations** are complete* and **detailed, demonstrating a sophisticated** understanding of surface-to-surface interactions and forces affecting adhesion. • Writes in **own words** using **common and scientific language.** *Responses include answers to all four bullet points in the prompt.	• **Explanations** are **complete*** demonstrating an understanding of surface-to-surface interactions and forces affecting adhesion. • **No clear inaccuracies** or misconceptions. • Mostly writes in **own words** using **common and scientific language.** *Responses include answers to all four bullet points in the prompt.	• **Explanations demonstrate a basic** understanding of surface-to-surface interactions and forces affecting adhesion. • **May contain inaccurate** or **incomplete** information. • Writes using **scientific language** only, **not always writing in own words**.	• Explanations are **missing important information.** • **Does not demonstrate a basic understanding** of surface interactions and forces affecting adhesion and/or **contains inaccuracies**. • Writing is **not in own words**.

Key Phrases & Descriptions:
The following examples have been excerpted from students' essays as illustrations of strong responses to different aspects (bullet points) of the writing prompt.

Describe the surface-to-surface interactions between gecko "setae" and a ceiling. Be sure to address the characteristics of both the setae and the surface. Include the shape, number, and size of setae in contact with the surface.	"Geckos have about one million hair-like seta on their feet. Seta can only be seen with a microscope, because they are near the nanoscale level. Each seta has up to one thousand spatulas branching off the end of it. The gecko can stick to the ceiling because the tiny spatulas get into the bumps on the surface of the surface. Even if the surfaces looks flat, at nano level it is full of bumps resembling small hills (Drawing 2)."  
Describe the variables affecting adhesion—the surface area, the surface contact, and the type of surface.	"If the gecko walks through dirt and gets his setae and spatulas dirty, it affects how he sticks, but it only takes five steps to clean off all the dirt. This does not work on other adhesive forces like tape. If the dirt increases on tape, the force it takes to pull it up decreases. If there is not a lot of surface contact the adhesive force is not as strong as the adhesive force with more surface contact. If the surface is dirty, it also affects the adhesive force making it not very strong." "Adhesion happens when something is compliant. Tape is compliant, because it can fill in the cracks of a surface. A table is not compliant, because it is not flexible and would not be able to fill in cracks. The more surface area the more adhesion you will have, like a bigger piece of tape. The smaller that piece of tape is divided in to, the more surface contact you will have. A big piece might just only touch the top of the cracks, but lots of tiny pieces may touch the sides and the bottom as well. If a surface has lots of cracks in it, the gecko can cling to it because of how the spatulas on the setae can fill in and cling to the cracks."

Explain how a lot of tiny adhesive forces overcome the force of gravity.	"Tiny adhesive forces like Van der Waals attractions are not affected by gravity because the tiny forces are too small to be affected. The electrical forces that allow a gecko to adhere have to be Van der Waals attraction. A gecko's setae has the opposite type of electrical charge than the surface the gecko is adhering to. The attraction between the surface and the gecko setae are not very strong, but with about one million setae the gecko has enough attraction to hold itself to the ceiling with one toe."
Describe the electrical forces and their role in gecko adhesion (i.e., interactions of charged particles between atoms of the spatula and the ceiling surface).	"But the spatulas fitting into the bumps is not how the gecko sticks. The gecko uses some thing called Van der Wall's. Van der Wall's works at the nano level. How it works is very interesting. The molecules at this level are positively, negatively, or neutrally charged. The positives are attracted to the negative and the neutral. The negatives are attracted to the positives and the neutrals. And the neutrals are attracted to the positives, negatives, and other neutrals. These are charged by electricity. Separate, these currents are weak, but together they can be extremely strong. These spatulas gain more power as they move across the surface. This causes them to gain extreme power and to be very sticky."

Misconceptions:
The following lists some common misconceptions students may have about adhesion:

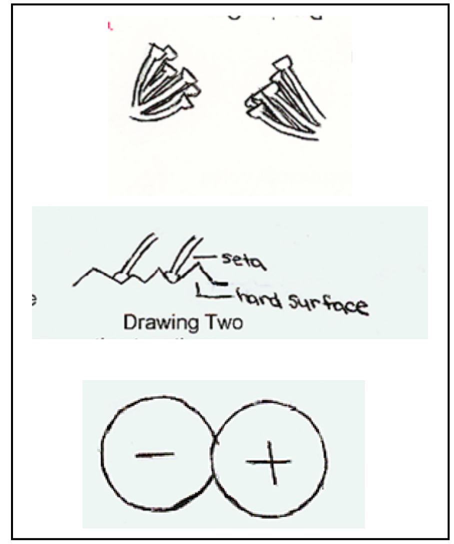
- Geckos stick with suction cups on their feet.
- Geckos' spatulas "hook onto" the nooks and crannies of the surface.
- Spatulas use micro-interlocking to adhere to the surface.
- The spatulas create friction so that the gecko sticks.

Anchor Papers Earning a "4" Score

Why 4? Sophisticated understanding. No content errors.

4

Geckos have about one million hair-like setae on their feet. Seta can only be seen with a microscope, because they are at the nanoscale level. Each seta has up to one thousand spatulas branching off the end of it. The gecko can stick to the ceiling because the tiny spatulas get into the bumps on the surface. Even if the surfaces looks flat, at nano level it is full of bumps resembling small hills (Drawing 2).



While geckos walk, the microscopic seta brushes against the surface. This force allows the gecko to stick to any surface it is on, including underwater and in many materials. All the tiny forces, the seta, overcome gravity because of the great amount of them. For the gecko to stick, the gecko and the surface have to have opposite charges to attract together (Drawing 3).

The adhesion force which the gecko uses gets activated by sliding of the geckos' seta. This force does not depend on the amount of humidity in the air and will work underwater. The gecko has a type of self-cleaning device that after it steps in dirt and continues to walk, the feet of the gecko will be clean. Each of the geckos' one million seta can hold up to 180 micro Newtons, which means all of them together can hold up to 180 Newtons. Even though the geckos have this many setae, only approximately twelve thousand seta are needed for the gecko to stick on the ceiling, since geckos only weigh 2.2 Newtons.

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How can a gecko adhere to the ceiling? The surface of a gecko's foot may fool you. It may look like just ridges and scales, but what it really is, is the little hairs that make up those ridges, and on those tiny hairs are even more tiny hairs that look like little spatulas. The tiny hairs that make up the ridges are called setae. They are about 60 micrometers long. The setae with the spatulas on them fit into the little nooks and crannies on surfaces such as a table or glass. The way these spatulas can do this is because the spatulas are so small they fit into the nooks and crannies on the surface. Also, as the gecko walk across the ceiling it builds up charges. The weak and temporary charges between the spatulas and the ceiling surface are the forces that hold the gecko to the ceiling, because there are so many of these spatulas to holds up the gecko.

But the spatulas fitting into the bumps is not how the gecko sticks. The gecko uses some thing called Van der Wall's. Van der Wall's works at the nano level. How it works is very interesting. The molecules at this level are positively, negatively, or neutrally charged. The positives are attracted to the negative and the neutral. The negatives are attracted to the positives and the neutrals. And the neutrals are attracted to the positives, negatives, and other neutrals. These are electrical forces. Separate, these currents are weak, but together they can be extremely strong. These spatulas gain more adhesion as they move across the surface. This causes them to gain extreme adhesion and to be very sticky.

If the gecko walks through dirt and gets his setae and spatulas dirty, it affects how he sticks, but it only takes five steps to clean off all the dirt. This does not work like other adhesive forces like tape. If the dirt increases on tape, the force it takes to pull it up decreases. If there is not a lot of surface contact the adhesive force is not as strong as the adhesive force with more surface contact. If the surface is dirty, it also affects the adhesive force making it not very strong.

How can adhesive force get equal to or greater than gravity that is pulling the gecko down? In order for a gecko to stick to the ceiling, there has to be the same amount of force both gravity and adhesive. For example, say gravity is pulling on the gecko 10 N. If gravity is pulling on the gecko more than the adhesive, the gecko would fall. It would not matter if the adhesive force were pulling more cause than it would stick better. Therefore, the adhesive forces and gravity have to be the same pull in order for the gecko to stick on the ceiling.

4

The gecko has lots and lots of setae to say the least. The setae are able to cling to the ceiling by the spatulas that each setae is divided into. The more surface area you have the better things will stick. The spatulas can be electrically charged making it able to adhere to the crack and ridges in a ceiling. The setae and spatulas are so small that you can only see them with special machines and without machines like that, we would never know the answer to "how the gecko can stick to the ceiling."

Adhesion happens when something is compliant. Tape is compliant, because it can fill in the cracks of a surface. A table is not compliant, because it is not flexible and would not be able to fill in cracks. The more surface area the more adhesion you will have, like a bigger piece of tape. The smaller that piece of tape is divided into, the more surface contact you will have. A big piece might just only touch the top of the cracks, but lots of tiny pieces may touch the sides and the bottom as well. If a surface has lots of cracks in it the gecko can cling to it because of how the spatulas on the setae can fill in and cling to the cracks.

The electromagnetic charge makes the cells on the spatula, be attracted to the surface it is on. The gecko has more seta then it needs because of all the surface area on one spatula. That is why the gecko can stay up on the ceiling for so long and can over come gravity.

The gecko used seta to cling to the ceiling. Each seta is divided into lots and lots of spatulas. The spatulas are made out of electrically charged atoms that are attracted to other atoms that make up surfaces that the gecko walks on. That is the reason why the seta that are on the gecko's feet can hold the gecko on the ceiling or on other surfaces.

Anchor Papers Earning a "3" Score

Why 3? *Needs More Detail.* No clear inaccuracies.

Key:
Needs more detail: gray highlight
3
When connecting the gecko billion of tiny seta find ways into the tiny ridges that can be found at the microscopic levels. The tiny seta, then use its charges, positive and negative to connect with the surface because it's so small. These tiny feet look like spatulas to help it cover more surface area.

There are many variables that effect whether something would stick to it or not, like surface area. Through experiments we have found out that no surfaces is exactly smooth so by the gecko having a billion tiny seta instead of one big one foot, its able to stick better. For the gecko though you could put it on any surface because unlike other adhesives that stop to stick, if they get wet or something the gecko uses positively and negatively charged atoms.

IF you have a billion little feet each one of those feet isn't going to really be strong like the big foot, but a billion little feet would start to create a very large force.

When the gecko sticks to the ceiling it doesn't have to worry about if it is wet, frozen, or anything because it uses some of the tiniest forces of electricity. Each and every little spatulas has two forces, half positive, half negative, and the solid surfaces has thousands of positive and negative forces and because opposites attract the full spatulas is sticking to the surface.

Needs more detail: Difficult to follow what make a surface more or less adhesive

---

3
This world is full of many amazing creatures and animals. One of these animals is the gecko. The gecko has the ability to adhere to most surfaces at any angle, even upside down. This ability is possible because the gecko has little hairs on the bottom of their feet called setae. These setae are so adhesive that a gecko can lift its own body weight with just one finger. Each seta is made up of several even smaller hairs called spatulas. The effect is similar to a paint brush.

Now the other part that makes a gecko so adhesive is the surface. Some people think that a table top is very smooth, when in fact, if you were to look at the same surface under a microscope, you would notice that it is very bumpy and rough. So now since the spatula-tipped seta are so small, they are able to fit into every nook and cranny of the surface, allowing the contact between the gecko and the surface to be very powerful.

Now this is where a thing called Van der Waal's Force comes into play. Van der Wall's Force is the attraction between two molecules. Since the seta are so small, they are able to feel the weak attraction between the molecules. This allows them to stick to the surface.

But there are many things that my decrease the effectiveness of the adhesion. The amount of dirt on the surface, the texture of the surface, and the amount of contact could all decrease this ability.

Gecko's have opened a gateway for society, now tons of research are being done on gecko's and their adhesive abilities.

Needs More Detail: Description of Van der Walls

3
The gecko has ridge like things on its toes. When you look closer they look like hairs which are called seta and at the end of those they have something called spatulas. The seta is about 20 micrometers longs and the spatulas are about 1 micrometer. The spatula is a triangle shape and they are used to hold the gecko up. There are over one million setae and over 10,000,000 spatulas on a gecko.

There are a lot of things that affect adhesion like water, shape of the surfaces and what you are trying to get to stick. Surface area has to do with adhesion because if there is more surface area, you can hold more up. If you don't have much contact area, you won't stick very good.

Each tiny force on the foot makes up for one big force like gravity because there are a lot of tiny forces. There are over 1 million tiny forces on the feet of the gecko.

On the gecko's foot it is a positive and the surface is negative and they act like magnets and stick to each other. The gecko can pull its seta back to make the force smaller.

Needs More Detail: Description of van der Walls or explanation of negative and positive charges.

Anchor Papers Earning a "2" Score

Why 2? Inaccurate, Off prompt, *Needs More Detail, Missing important Information.*

Key:

Inaccurate: Underline Highlight

Off prompt: ~~Strikethrough Highlight~~

Missing Information: gray highlight

2

The way the gecko adheres to the ceiling has been a mystery for many years. We have finally come to a conclusion. The gecko has nano-sized hairs on the bottom of his feet called "setae." Those setae have little things called "spatulas" on the tips of them. The setae fills in all of the bumps and flaws in the hard surface. This makes him stick to all surfaces. The setae look like hairs. The gecko had positive and negative changes on its feet which connect with the neutral charges of objects.

Needs More Detail: Surface to surface interaction; How adhesion overcomes the force of gravity; Role of electrical forces and adhesion

Missing Information: Variables affecting adhesion

2
How do geckos adhere to surfaces?

Geckos are one of the most amazing animals because of how they adhere to surfaces. There are many ways the geckos can adhere to a surface. The mechanism a gecko could use is electrical, vacuum, air pressure, friction, magnetism, static electricity, capillary wet adhesion, suction, and micro-interlocking (Velcro). At first I thought the gecko used capillary wet adhesion but we ruled it out because it did not leave a wet trail. Geckos adhere to surfaces such as glass, wood, metal, and many other surfaces. Geckos have hairs called setae on their feet and at the end of those setae are spatulas. The spatulas make the feet have a lot of surface contact. The spatulas have a lot more surface contact because they get into all the nooks and crannies. If it had just the foot, it would not make a lot of surface contact compared to how much contact the spatulas make. The spatulas are dragged across the surface; they act like as if they were a liquid. Geckos have enough surface contact that it only needs one feet to hold on to its surface. Setae look like little strands of hair. The gecko has about 100,000,000 – 1,000,000,000 spatulas and about 1,000,000 setae. So many tiny spatulas over come the force of gravity because the setae has such great surface contact. The spatulas and the ceiling surface are both neutrally charged things so they both attract. It is not all that clear and concise on how geckos stick to the ceiling, but after this unit I really began to understand the way a gecko adheres to surfaces like wood and glass.

Inaccuracy: Unclear which of the adhesion mechanisms were discarded; pretty sure how the gecko adheres

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2
Geckos can adhere to a ceiling

Geckos have tiny hairs call setaes and at the end of setaes is a suction cup like called spatulas. They need 12,222 setas to hold a gecko up and they have a million setas on a gecko. Also they have 1 billion spatulas. They are what holds them up the ceiling. The spatulas get in the nooks and grooves of surfaces that is why they stay up. Geckos have a attractive force which is called van der Waal's attraction. Also a gecko has 180 micro newtons of force. It is a mystery how geckos have consistent electrical force, regardless of speed, humidity, underwater. A gecko can walk without falling. Also, their feet are always clean because they clean themselves.

Inaccuracy: Spatula is not a suction cup.

Anchor Papers Earning a "1" Score

Why 1? Inaccurate, Off prompt, *Needs More Detail, Missing vital Information.*

Key:

Inaccurate: Underline Highlight

Off prompt: ~~Strikethrough Highlight~~

Missing Information: gray highlight

1

How does a gecko adhere to the ceiling?
The gecko adheres to the ceiling with its setae. Setae are tiny hairs on the foot. At the tip of the setae are shaped like little spatulas. There are tiny hairs that are the tips of the setae. Then, there's smaller hairs on that tiny hair. There are so many little hairs that they fit in the bumps and crevices. Then the molecules of the surface attract making a charge. So that is how they can walk on the ceiling.

Missing Information: More detail is needed to explain surfaces, electrical forces and their role in adhesion, and variables affecting adhesion.

1
The gecko can adhere to a ceiling because of the many ways nano fibers on their satae. The Setae consists of millions (maybe even more) tiny hairs that produce adhesion to a molecular level.

Missing Information: More detail is needed to explain surfaces, electrical forces and their role in adhesion, and variables affecting adhesion. Doesn't really fully answer the prompt.

1
How adhere sticks to ceilings is that geckos have seta. Seta are tiny hairs that help geckos stick to ceilings. One piece of seta is about 20 Mm. On every tip of a seta looks like a spatula. A ceiling is flat and sometimes smooth a seta is like a suction. It traps the little places so it can stick on things.

The surface area is bumpy and the gecko could fall because ~~the ceiling could have the little white foam things and it could just fall cause the one could loosen up and the pieces would fall.~~ The adhesive forces the more of a chance to hold onto the ceiling the less forces the more of chance falling from the ceiling.

The gecko use molecules like Vander attractions Vander waals forces.

Appendix B: NanoLeap Physical Science Vocabulary for Lesson 8

Atom
One of the minute indivisible particles of which matter is composed. It is made up of a nucleus, composed of protons and neutrons, and electrons that orbit the nucleus.

Electron
An elementary particle consisting of a negative charge that orbits a nucleus of an atom

Electron cloud
1. The system of electrons surrounding the nucleus of an atom
2. A region in which electrons surrounding the nucleus of an atom are most likely to be found

Nanotube
A microscopic tube whose diameter is measured in nanometers: These are almost always carbon nanotubes, referring to the wires of pure carbon that look like rolled sheets of graphite.

Negatively charged
Having more electrons than protons, and having a lower electrical potential

Nucleus
The positively charged central portion of an atom that comprises nearly all of the atomic mass and that consists of protons and usually neutrons

Positively charged
Having more protons than electrons, and having a higher electric potential

Proton
An elementary particle identical to the nucleus of the hydrogen atom that, along with the neutron, is a constituent of all other atomic nuclei, and carries a positive charge numerically equal to the negative charge carried by an electron