ACTIVITY 8

Investigating a Pathogen

CARD-BASED INVESTIGATION

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ACTIVITY SUMMARY

Students evaluate information related to identifying the pathogen causing Southsand fever. They evaluate laboratory evidence to deduce the biological cause of the Southsand fever outbreak. Students apply the metacognitive scientific skills they've been practicing throughout the unit to investigate the disease, using microscope images. Based on the information they've gathered, students develop an explanation about which pathogen causes Southsand fever and how people become infected.

ACTIVITY TYPE
CARD-BASED INVESTIGATION

NUMBER OF 40–50 MINUTE CLASS PERIODS
1-2

KEY CONCEPTS & PROCESS SKILLS

1. Slow thinking relies on careful reasoning and is useful for complex or higher-stakes situations. Slow thinking takes time and effort but is less prone to cognitive error when evaluating information and reaching conclusions.
2. Common scientific practices are designed to support slow thinking, which makes scientific conclusions more reliable.
3. An actively open mindset helps reduce errors from cognitive biases and cognitive shortcuts by deliberately seeking out new ideas and information that could change one's mind.

NEXT GENERATION SCIENCE STANDARDS (NGSS) CONNECTIONS:

Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. *(Science and Engineering Practice: Engaging in Argument From Evidence)*

Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence. *(Science and Engineering Practice: Engaging in Argument From Evidence)*

CONCEPTUAL TOOLS

VOCABULARY DEVELOPMENT

cell culture
(assumed prior knowledge)
the process of growing cells under controlled conditions outside of their natural environment

eukaryotes
(assumed prior knowledge)
organisms whose cells contain a nucleus

microbe
(assumed prior knowledge)
a microscopic cellular organism or a virus

pathogen
an organism or biological agent that causes infectious disease

prokaryotes
(assumed prior knowledge)
cells that do not have a nucleus, and their DNA is located in the cytoplasm of the cell

protist
(assumed prior knowledge)
an organism made up of a single cell or many cells with a nucleus and that is not an animal, plant, or fungus

protozoa
(assumed prior knowledge)
types of protists that are unicellular eukaryotes

spore
(assumed prior knowledge)
a reproductive cell that can develop into a new individual without fusing with another reproductive cell

TEACHER BACKGROUND INFORMATION

Koch's Postulates

The first infectious disease organism that was identified by microscope, *Mycobacterium tuberculosis*, is credited to German scientist Robert Koch in 1882. Koch won a Nobel prize for his work, which became the foundation of studying infectious diseases. Through his research, he came up with the following four postulates (guiding principles) that experiments would need to confirm in order to show that a pathogen causes a disease. Koch's four postulates are:

- The microorganism must be found in abundance in all organisms suffering from the disease but should not be found in healthy organisms.
- The microorganism must be isolated from a diseased organism and grown in pure culture.
- The cultured microorganism should cause disease when introduced into a healthy organism.
- The microorganism must be re-isolated from the inoculated, diseased experimental host and identified as being identical to the original specific causative agent.

Subsequent research has shown that the first postulate is not true in all cases. For example, some diseases can cause someone to carry an infectious pathogen, while they do not develop the disease themselves.

Valley Fever

Valley fever is caused by a fungal pathogen, *Coccidioides immitis*, that lives in soil and dust in certain areas. When disturbed, the fungal spores can become airborne and inhaled, leading to disease (coccidioidomycosis) in some people and other animals. *Coccidioides* most commonly infects rodents, dogs, and humans but can sometimes infect cats and livestock. Valley fever primarily affects the lungs and can cause flu-like symptoms such as cough, fever, chest pain, fatigue, and shortness of breath. In severe cases, the infection can spread from the lungs to other parts of the body—including the skin, bones, and central nervous system—leading to more serious complications, such as meningitis or, rarely, death. Valley fever is often misdiagnosed as pneumonia or lung cancer due to the appearance of spherule masses in lung X-rays. The populations most at risk for the disease include people of African or Filipino descent; people with frequent contact to outdoor dusty/windy conditions; and people with compromised immune systems, including those over age 60 and pregnant people.

Valley fever is prevalent in arid and semi-arid regions, particularly in the Southwestern United States—including Arizona, California, Nevada, New Mexico, Texas, and Utah—as well as parts of Mexico, Central America, and South America. The majority of identified cases occur in Arizona and California. However, climate change has influenced how this pathogen and many other fungi grow and spread around the world. Some scientists think that *Coccidioides* will be found as far north as the Canadian border by 2100.

Modern diagnosis of Valley fever can be accomplished through antibody blood test, skin test, cell culture, and microscope analysis. The blood test is the most accurate and is less invasive than some of the other diagnostics. Treatment typically involves antifungal medications such as fluconazole or itraconazole, especially for severe or disseminated cases where the disease spreads throughout the body. People suffering severe forms of the disease may need hospitalization and prolonged treatment (months or years). In many cases, patients cannot be cured of the disease and will need treatment for the rest of their lives.

Researchers are actively studying Valley fever to better understand its epidemiology, improve diagnostic methods, and develop effective treatments and vaccines. Studies are focusing on identifying genetic factors that contribute to susceptibility, understanding the environmental conditions that facilitate the spread of the fungus, and exploring potential new antifungal therapies and preventive measures. A vaccine for dogs is currently in development, which could pave the way for a human vaccine.

MATERIALS & ADVANCE PREPARATION

FOR THE TEACHER

- VISUAL AID 8.1 "Pathogen Taken From the Soil"
- VISUAL AID 8.2 "Southsand Fever Infection Cycle"

FOR EACH GROUP OF FOUR STUDENTS

- SET OF PATHOGEN TYPE CARDS (4 cards)

If you have the time and equipment, consider having students complete a microscope investigation before this activity to enhance the biology content of the activity. Find sample organisms that correspond to the general types of pathogens that students will see in the activity (i.e., bacteria, prokaryotes, and fungi). You can use prepared slides or live samples. Common sources for live samples to look at under the microscope include pond water for protozoa, yogurt for bacteria, and baker's yeast for fungi. Viruses are not able to be seen with the light microscopes that are common in most classrooms, but you can provide a variety of electron-microscope images for students to examine instead.

TEACHING NOTES

Suggestions for **discussion questions** are highlighted in gold.

Strategies for the **equitable inclusion of diverse students** are highlighted in light blue.

GETTING STARTED (10 MIN)

1 Review the findings from the epidemiology investigation game in Activity 6.

- Let students know that they are going to continue the investigation into Southsand fever. Ask, What are the key findings from the epidemiology investigation from Activity 6? Student responses may vary, but important information should include that most people who became ill from the disease were exposed to areas with soil (e.g., outdoor workers) and that based on multiple cases, the disease is not contagious (spread from person to person).
- Have students read the Introduction in the Student Book. Review the term *pathogen* with students. If appropriate, you may want to have students review ideas related to prokaryotic and eukaryotic cells in the Science Review at the end of the activity.

TEACHER'S NOTE: Please do not provide any information about Valley fever, the illness that Southsand fever is modeled after, until after the completion of this activity.

- If you decided to run the optional laboratory microscope investigation (see Advance Preparation), do so before students begin the Procedure.
- Let students know that they will be looking at evidence and images related to microbes to try to figure out the Southsand fever pathogen. Inform them that most specimens in the images are dyed or colorized by computer to reveal features and are not actually the color presented.

PROCEDURE SUPPORT (30 MIN)

2 Students examine information about different pathogens.

- As a class or in their groups, have students read the fictional scenario in Procedure Step 1. Remind students to use an actively open mindset when approaching the evidence in the activity.

- Use the diagram in the Introduction to review the relative and absolute sizes of the pathogens students will be investigating. Students may need additional support converting between units of nanometers (nm), micrometers (μm), millimeters (mm), and centimeters (cm).

- In Procedure Step 2, hand out a set of Pathogen Type cards to each group of four students and have students read the cards. Clarify any questions about the information on the cards. If you have students who may require more support analyzing the information about the pathogens, consider assigning these students to the virus or bacteria pathogens, which are simpler pathogens with less information to synthesize.

3 Have a class discussion about the different types of pathogens and which ones are unlikely to be the Southsand fever pathogen.

- When reviewing student responses to Procedure Step 4, ask, Do you have enough information to make a claim, or would you like additional information? Student responses will vary, with some feeling that they can identify the pathogen and others not as sure.

Sample Student Response, Procedure Step 4

I think the type of pathogen is likely to be a protozoa. Viruses can't be the pathogen because they are not made of cells, and the pathogen found in the patient sample is made of cells. Bacteria can't be the pathogen because they are very small. The Southsand fever pathogen is much larger than bacteria and has cells with a nucleus. Protozoa is within the right size range, and the images look similar to the Southsand fever pathogen.

- In Procedure Step 5, have each group share their ideas and evidence about which pathogens are likely to be the Southsand fever pathogen. Discuss the importance of first approaching the question using a process of elimination. Students should be able to eliminate viruses and bacteria. That leaves protozoa and fungi as possibilities. Students should notice that the images look similar to protozoa and not similar to fungi. This should lead students to believe, at this point, that it is a protozoan.

4 Students get additional evidence and adjust their claims about the pathogen.

- In Procedure Step 8, students gain more evidence through the fictional scenario. This information should lead students to think more about their conclusions from Procedure Step 4. The growth in the petri dish looks like mold, and the microscope image does not look like protozoa. The only image on the Pathogen Type cards that is similar to the microscope slide is the bottom image on the Fungi card (Card 4). Students should see that this evidence contradicts their initial conclusion that the pathogen is protozoa.

- In Procedure Step 9 when students revisit their predictions, they should be able to narrow down the possibilities to fungus as the pathogen. This is a good time to discuss the quantity and quality of the evidence provided.

Sample Student Response, Procedure Step 9

The evidence doesn't support the claim that the pathogen is protozoa. Under the microscope slide, it doesn't look like protozoa. It looks more like fungi. Also, it is found in dry soil.

- Ask, What are some possible alternative explanations for what you saw in Procedure Step 10? Student responses could vary, but here are three of the most likely:
  - The organism growing on the petri dish is not *Coccidioides* but is some other protozoa.
  - The organism growing on the petri dish is caused by something that has contaminated the sample, because it looks like mold.
  - The organism growing on the petri dish is mold because that's what's causing Southsand fever.
- Use Visual Aid 8.1, "Pathogen Taken From the Soil," to confirm that the pathogen looks like a picture of the pathogen isolated from a soil sample. These two matching images should confirm for students that the pathogen is fungi.
- In Procedure Step 11, have groups share their claims about what type of pathogen causes Southsand fever and how people become infected. Ask students what their strongest evidence is that supports their claims and if there is any evidence that counters their ideas.

Sample Student Response, Procedure Step 11

The pathogen type is fungi because it is too large to be viruses or bacteria. It has a nucleus, and it looks like the petri-dish mold from the scenario and also the yeast. Infection most likely occurs in Southsand by breathing in dry particles of fungi from the soil, especially at construction sites. We learned this in Activity 6. Inside the body, the pathogen looks more like a yeast in the lungs of people. Outside the body, the pathogen looks like a mold in the petri dish when it is cultured. In the soil, it looks like a fungus.

- Use Visual Aid 8.2, "Southsand Fever Infection Cycle," to review the important information about the Southsand fever disease so all groups get on the same page about the disease pathogen and how it infects people. Southsand fever is caused by fungi that live in the soil. When the fungal particles get disturbed, they enter the air by wind and can then be inhaled by humans and other animals. Once in the lungs, the infection takes hold, causing respiratory symptoms. Since the respiratory symptoms are not caused by viruses or bacteria, they can't be treated with antiviral or antibiotic medications.
- If appropriate for your students, introduce and explore dimorphic fungus. Dimorphic fungi change their structure based on the temperature. In cold soils, they grow as mold with spores. In the warm human body, they transform into large, round, yeast-like structures (spherules) to reproduce and evade the immune system.
- In Procedure Step 12, ask students to look for problems in the thinking (and behavior!) of the scientist in the fictional scenario. Students should see the fast thinking and/or confirmation bias of the scientist who used one piece of information *(the petri dish looks like it has mold in it)* to confirm what he believed. Use the opportunity to discuss how cognitive shortcuts and cognitive biases can affect how evidence is used to draw conclusions.

Sample Student Response, Procedure Step 12

There was fast thinking when the scientist assumed the petri dish was contaminated, and he put it aside. It was fast thinking because he used the availability shortcut to jump to the conclusion that it was like something else he had experienced. He slowed down his thinking after he got sick from it! The fact that he was careless with the petri dishes showed confirmation bias because he had decided the pathogen was not in the dish. One way he dealt with it was to have an actively open mindset and look for the new evidence that related to his experience and be open to new ideas about the pathogen.

SYNTHESIS OF IDEAS (10-20 MIN)

5 **Use the Build Understanding items to consider the metacognitive approaches used in scientific investigation.**

- In Build Understanding item 2 and Connections to Everyday Life item 3, students should easily be able to identify the confirmation bias and aspects of an actively open mindset in the scenario on the part of the researcher. Encourage students to also think about their own metacognition during the investigation. Ask, What caused you to change your mind about the pathogen? Students should point out that new information and considering the evidence for and against the previous claim made them open to alternative explanations. These are central ideas of an actively open mindset.

- A critical takeaway for students in this activity is to see that while an actively open mindset can apply to everyday experiences, as explored earlier in this unit, the approach is also central to achieving reliable results in a scientific investigation.

6 **Reveal that the fictional Southsand fever disease is based on a real disease called Valley fever.**

- After students have confirmed what the pathogen is, reveal that Southsand fever is modeled after Valley fever, also known as coccidioidomycosis, and is caused by a fungus called *Coccidioides*. It follows an infection cycle like the one shown in Visual Aid 8.2.

- Share with students that the pathogen investigation in this activity loosely follows the historical investigation of the *Coccidioides* fungus, which occurred during the late 1800s and early 1900s. *Coccidioides* was initially misclassified as a protozoa, culture samples were thought to be contaminated, and there was confirmation bias and authority bias present in the early investigations. The true nature of the disease was determined through careful studies, using experiments on guinea pigs and rabbits to transmit the disease to healthy animals by injecting the animals with tissue samples from infected patients. A breakthrough in the study of the disease came from a mishap in the lab when a medical student got sick after breathing in dust from an old sample petri dish.

Finally, the disease transmission was connected to the soil after the fungal pathogen was isolated from the soil that was under the living quarters of a group of farm workers who came down with the disease.

- Be clear that while the case study used throughout the unit is inspired by Valley fever research and data, it was modified to fit the Southsand fever disease scenario. Make sure students understand that Southsand fever is NOT a real disease, even though it is modeled after one.
- Conclude the activity by revisiting the Guiding Question, *How do epidemiologists use an actively open mindset?* Use this as a chance to revisit and summarize the key concepts and process skills of the activity, especially those related to evidence for and against an idea.

SAMPLE STUDENT RESPONSES

BUILD UNDERSTANDING

① **What is the pathogen of Southsand fever? Use the evidence from this activity to make a claim about the pathogen type and how it appears inside the body and in the soil. Include your reasoning.**

The pathogen is fungi because it is too large to be viruses or bacteria. It has a nucleus, and it looks like the petri-dish mold from the scenario. It also matches the yeast image, which is evidence that it is fungi. The last piece of evidence was that we confirmed that the pathogen from the body looks like the pathogen isolated from a soil sample. We know the pathogen is in the soil from Activity 6. Outside of the body, it looks like the mold in the petri dish. Inside the lungs, it looks more like protozoa but is actually a yeast.

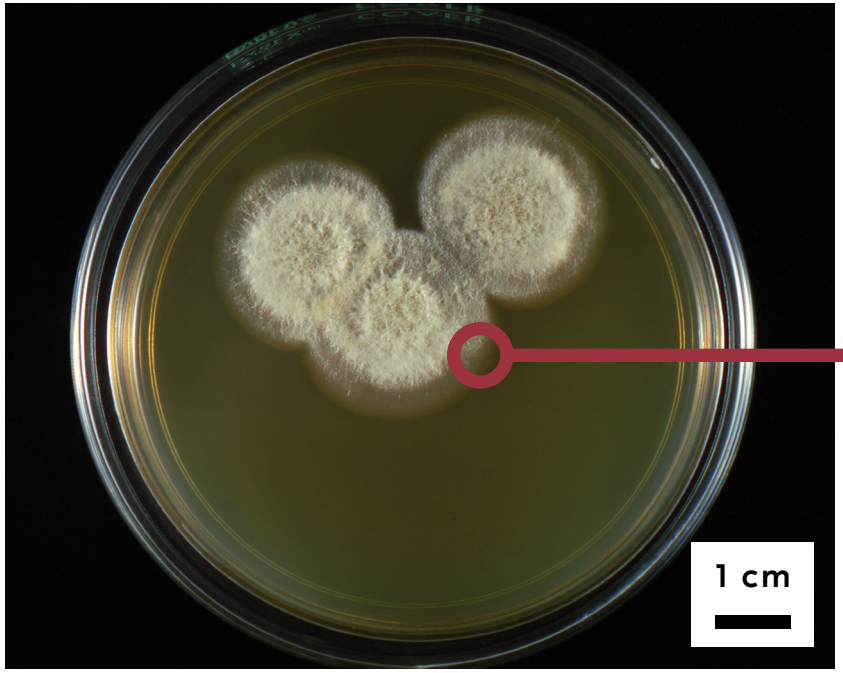
② **How did confirmation bias appear in the investigation to identify the pathogen?**

There was confirmation bias when the researcher decided to ignore the mold growing on the petri plates as a contaminant instead of considering the alternative possibility that the mold was the actual pathogen.

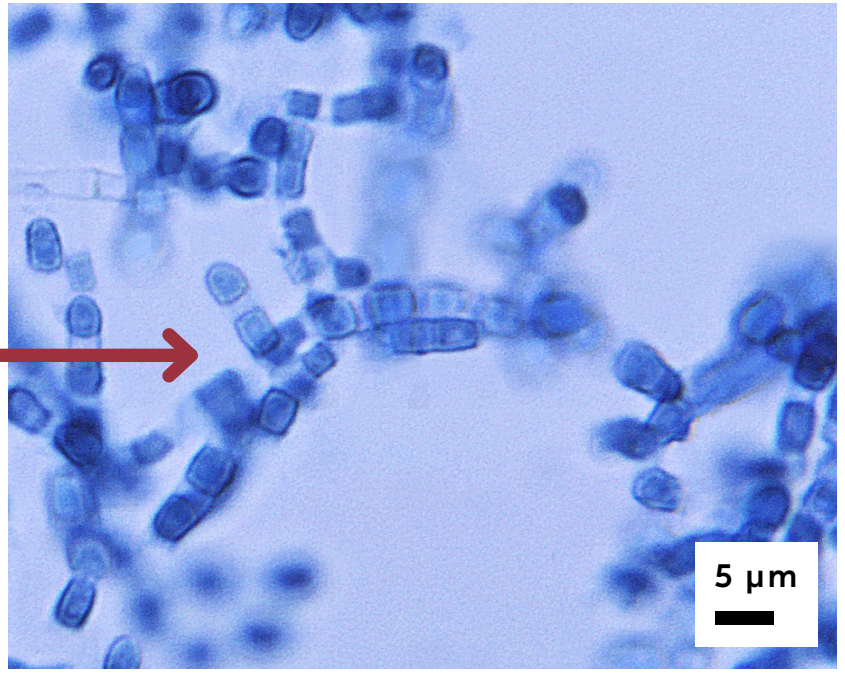
CONNECTIONS TO EVERYDAY LIFE

③ **What were the most important aspects of an actively open mindset you used to identify the pathogen in this activity? Explain.**

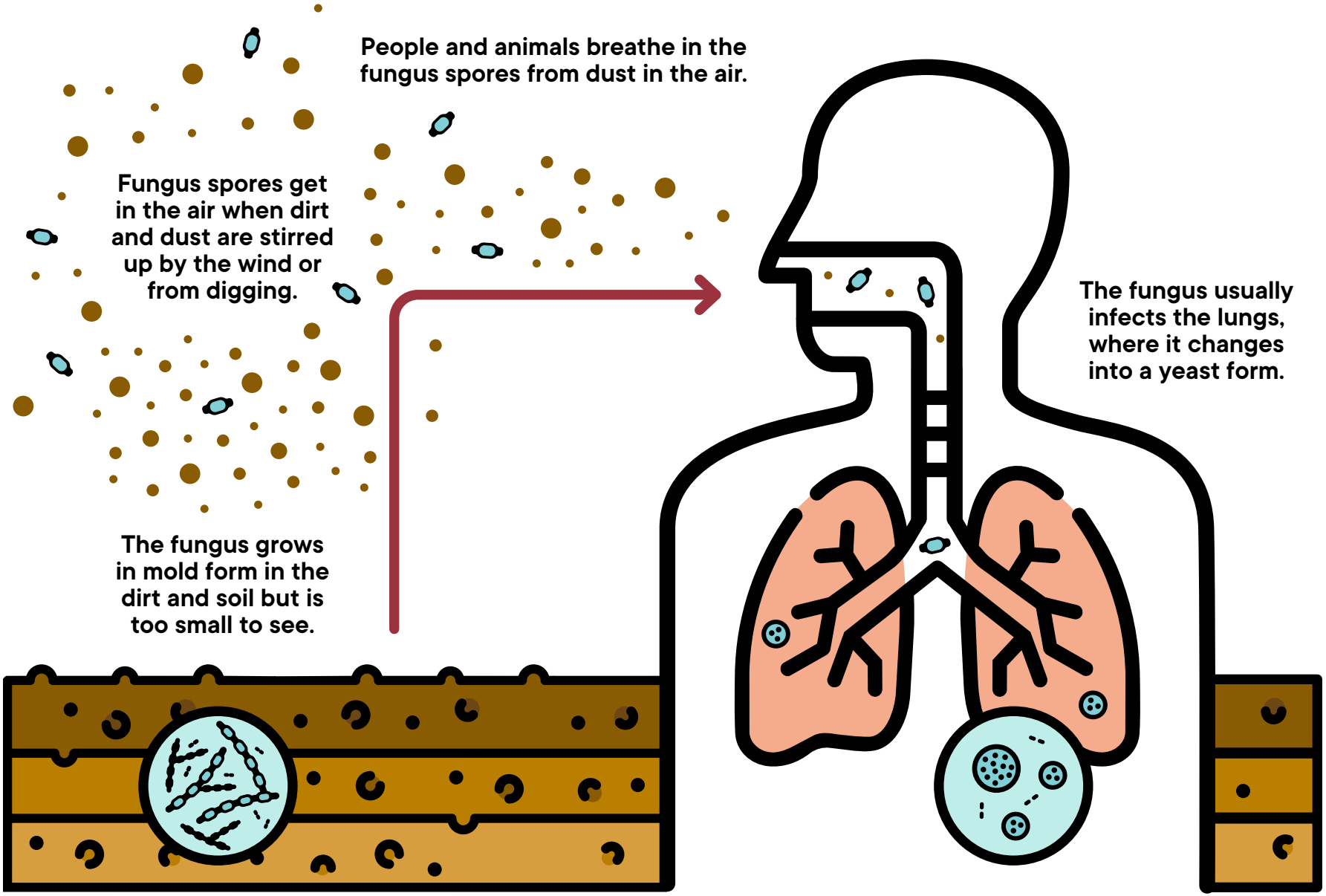
The most important was considering possible alternative explanations for the mold by considering that the mold in the petri dishes was not a mistake. Also important was knowing that there was a need for new evidence.



The pathogen taken from soil and grown in a petri dish.



Microscope image of the organism from the same petri dish.

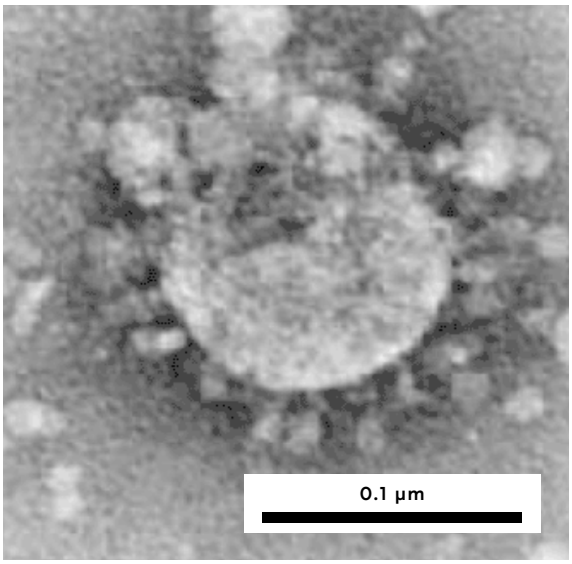

People and animals breathe in the fungus spores from dust in the air.
Fungus spores get in the air when dirt and dust are stirred up by the wind or from digging.
The fungus usually infects the lungs, where it changes into a yeast form.
The fungus grows in mold form in the dirt and soil but is too small to see.

CARD 1

PATHOGEN TYPE: VIRUSES

- Genetic material inside a protein shell
- Not a cell itself (so no cell membrane, cytoplasm, or nucleus)
- Needs to infect a host cell to reproduce
- Size: 20 nanometers–400 nanometers

EXAMPLE DISEASES WITH THIS PATHOGEN:
influenza (flu), COVID-19, bird flu, rotavirus, Ebola, HIV/AIDS



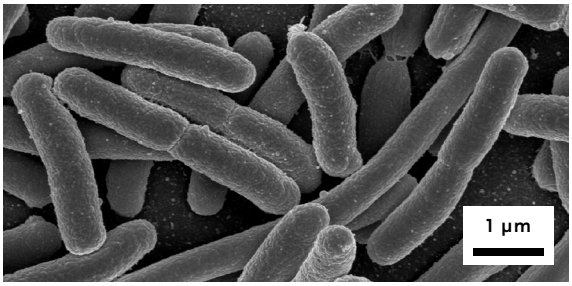
Electron microscope image of SARS-CoV, the virus that causes COVID-19.

CARD 2

PATHOGEN TYPE: BACTERIA

- Single-celled organism without a nucleus
- Bacteria thrive in moist conditions including soil, water, and food and inside other organisms
- Some can survive in extreme environments—such as very dry, cold, hot, or salty environments
- Size: length: ~1 —10 micrometers
  width: 0.2 —1 micrometers

EXAMPLE DISEASES WITH THIS PATHOGEN:
tuberculosis (TB), bronchitis, sepsis infection



TOP Groups of *Escherichia coli* cells growing on a petri dish in the lab. Each small cluster of cells can contain millions of bacterial cells.

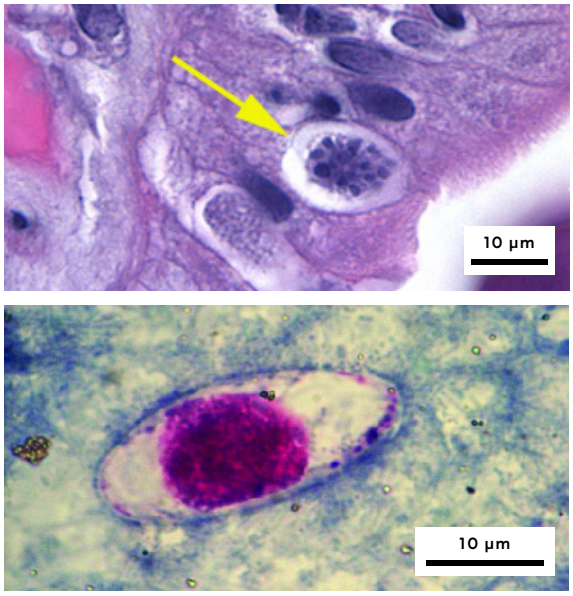
BOTTOM Electron microscope image of *Escherichia coli* bacteria.

CARD 3

PATHOGEN TYPE: PROTOZOA

- A single-celled organisms with a nucleus
- Almost all need moist environments to survive—such as water, moist soil, or inside another organism
- Some can change their form depending on the environment
- Can reproduce in multiple ways, including by a spore-like form
- Size: ~5—1,000 micrometers

EXAMPLE DISEASES WITH THIS PATHOGEN:
malaria, toxoplasmosis



TOP Microscope image of Cystoisospora belli, a type of *Coccidian* protozoa, in animal intestines. The yellow arrow points to a spore containing many protozoan cells.

BOTTOM A microscope image of an individual cell of *Cystoisospora belli* in a different form.

SCIENTIFIC THINKING FOR ALL: A TOOLKIT • UNIT 5: SKILLS TO EVALUATE THINKING, ACTIVITY 8: PATHOGEN TYPE CARDS

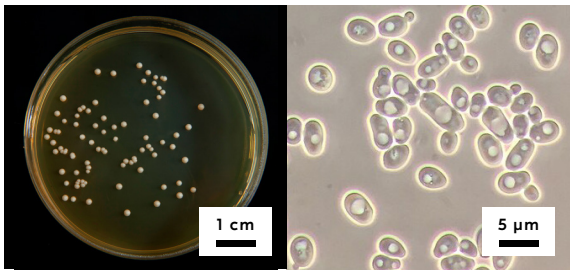
CARD 4

PATHOGEN TYPE: FUNGI

- A single-celled or multicellular organism with a nucleus
- Most live in dead matter or soil, but some can be pathogens inside organisms
- Some change form between yeast (single-celled) and mold (multicellular), depending on conditions
- Can reproduce in multiple ways, including by spores
- Size range: single-celled: ~5–40 micrometers
  multicellular: up to several meters

EXAMPLE DISEASES WITH THIS PATHOGEN:
ringworm, cryptococcosis

YEAST FORM



MOLD FORM

TOP *Saccharomyces cerevisiae* yeast grown on a petri dish (left) and viewed under a microscope (right).

BOTTOM *Aspergillus fumigatus* mold grown on a petri dish (left) and viewed under a microscope (right).

SCIENTIFIC THINKING FOR ALL: A TOOLKIT • UNIT 5: SKILLS TO EVALUATE THINKING, ACTIVITY 8: PATHOGEN TYPE CARDS