ANTIBIOTICS

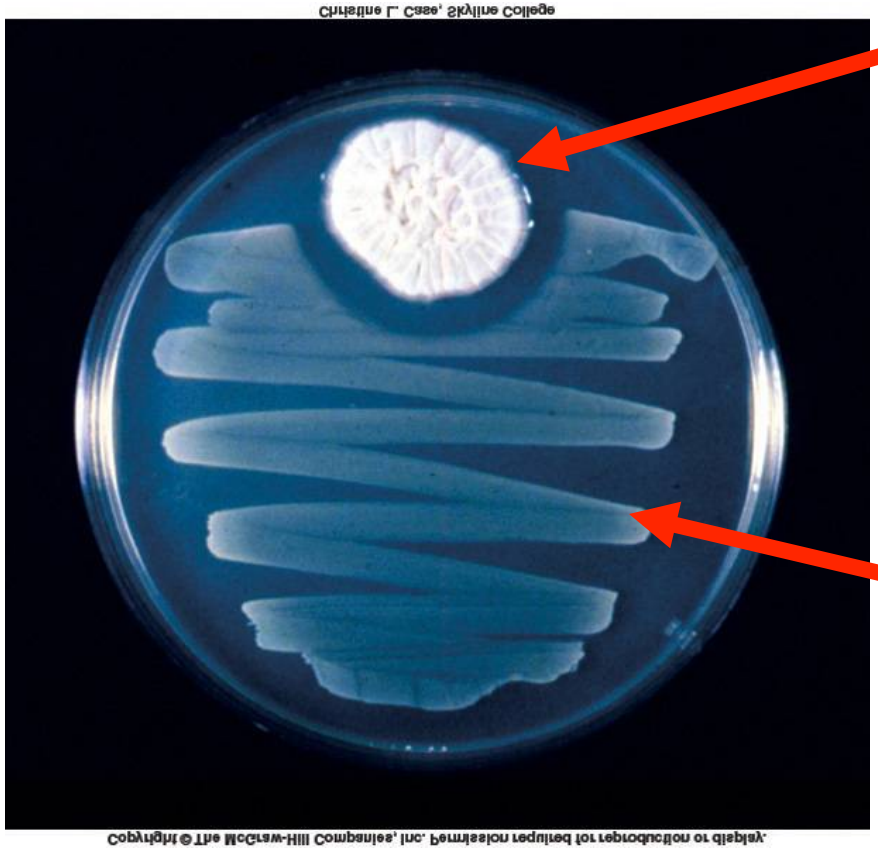
Credit: neur0nz @Flickr

Learning Targets

- What are antibiotics?
- Where do they come from?
- How does our antibiotic, streptomycin, kill bacteria?

Discovery of Antibiotics

In 1928, Alexander Fleming discovered the first antibiotic.



A fungus (*Penicillium*)

inhibited the growth of…

A bacterium (*Staphylococcus*)

What are Antibiotics?

- Antibiotics—chemicals made and secreted by some organisms make to inhibit the growth of other organisms.
  - The word literally means “against life.”

- We use antibiotics to stop bacterial infections in humans.

How do Antibiotics Work?

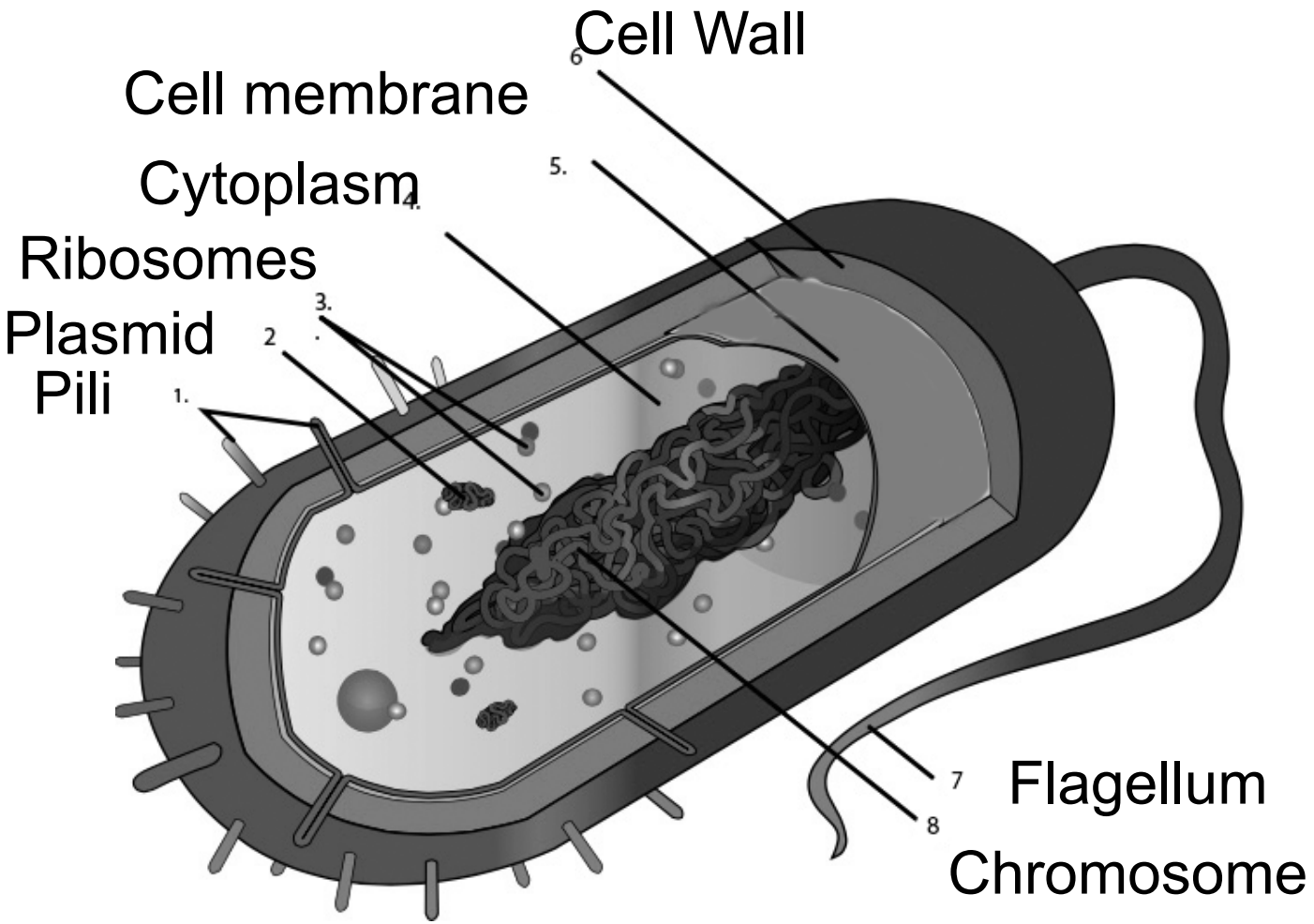
- To be useful to humans, the antibiotic must have selective toxicity.

- It must prevent the growth of some organisms (bacteria) but not harm or prevent the growth in other organisms (humans).

Criteria for Antibiotic Targets

- Target needs to be a structure, enzyme or chemical pathway that humans do not have.

Return to Worksheet



Check Points

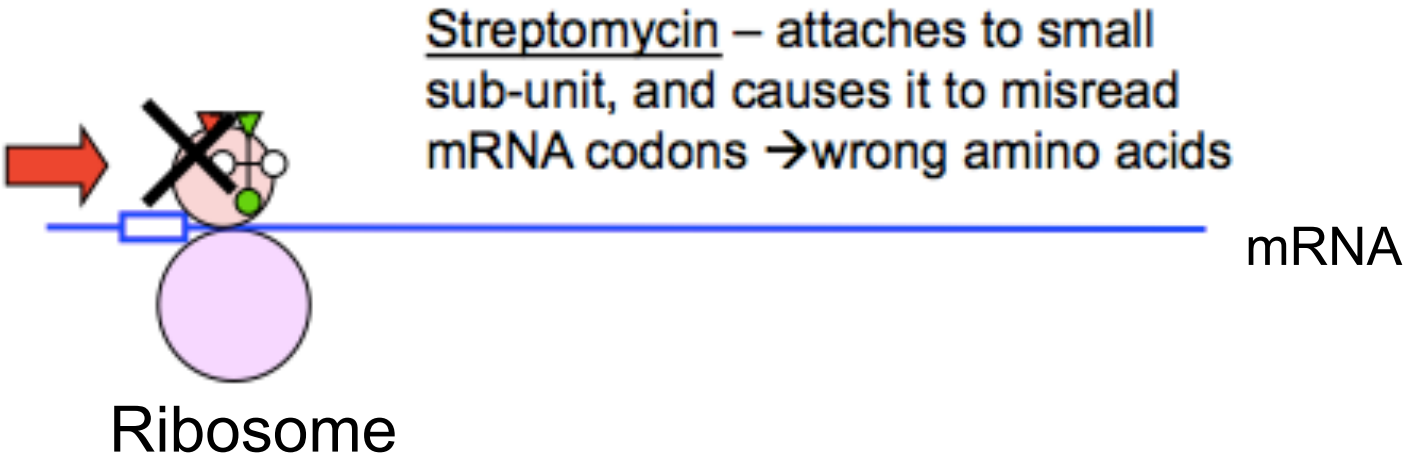
- What bacterial cell structures might be good targets for antibiotics?

Possible Targets

- Cell wall synthesis
- Protein synthesis – bacteria ribosomes are different from human ribosomes
- DNA replication – enzymes are different.

How does our antibiotic, streptomycin, work?

- Inhibits protein synthesis during translation.



How does our antibiotic, streptomycin, work?

- Streptomycin binds to the bacterial ribosome and changes the ribosome shape slightly.
- The wrong tRNA can attach so the mRNA is mis-read.
- A random, non-functional protein is made.
- End result: Bacteria dies.

Review

- What are antibiotics?
- Where do they come from?
- How do our antibiotic, streptomycin, work?

Antibiotic Resistance

http://iconsinmedicine.wordpress.com/

Learning Targets

- What strategies do bacteria use to fight antibiotics?
- Specifically, what strategies do *B. megaterium* use to fight streptomycin?
- How do bacteria get these strategies?

Antibiotic Resistance

- Different bacteria use different resistance strategies.
- Some bacteria use multiple strategies.

http://laboratory-manager.advanceweb.com/Features/Articles/Tackling-Antibiotic-Resistance.aspx

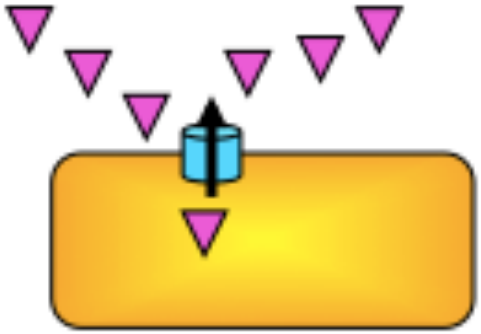
Antibiotic Resistance Strategies

- Produce enzymes that break down the antibiotic.
- Alter cell membrane proteins so antibiotic cannot enter the cell.
- Alter the shape of the antibiotic target, i.e., alter the shape of ribosomes.
- Pump the antibiotic back out with transport proteins called efflux pumps.

Bacillus megaterium's Resistance Strategies

Strategy 1:
Actively pump antibiotic out of cell.

Cell Level:



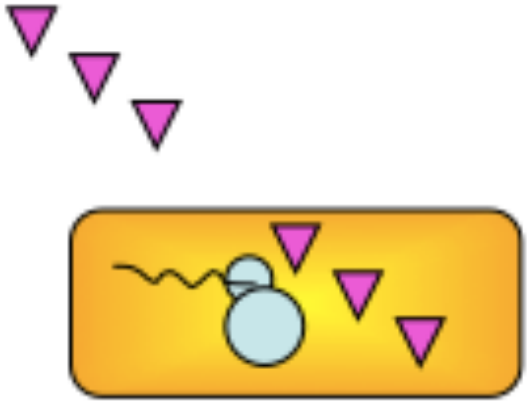
Efflux Pumps

DNA Level: Mutation that causes over-expression of gene for pumps → more efflux pumps in cell membrane.

Bacillus megaterium's Resistance Strategies

Strategy 2: Ribosome shape changes slightly and antibiotic can no longer bind to it.

Cell Level:



DNA Level: Mutation in ribosomal RNA gene

Summary Check Point

- What are 3 general strategies that bacteria use to fight antibiotics?
- What are the two strategies *Bacillus megaterium* uses to fight against antibiotics?
- How do bacteria get these strategies?

Extra slides below about degrees of resistance. May be Useful to come back to these after students wrestle with above ideas

Natural Selection Model

Before selection

Over time, mutations occur in the population.

After selection

Antibiotics Introduced

Only resistant bacteria survive.

Final population

Resistant bacteria reproduce.

Antibiotic misuse

- When you don’t take all of your antibiotic pills you’re selecting for the most resistant bacteria
- Low levels of antibiotics in live stock select for the most resistant bacteria

Introduction

We are going to look at how change occurs in a large, sexually reproducing population: mountain sheep.

We'll be developing ideas that we can apply to all the other populations.

Introduction: Mountain Sheep

Mountain sheep are found in the Rocky Mountains of the United States and Canada. The males have large curved horns. Generally, the sheep are found in herds of many females and only one mature male. The males compete for females in order to reproduce. Male sheep live from 9 to 12 years.

Introduction: Mountain Sheep

Recently, people have noticed a change in the mountain sheep population. Specifically, in comparison to the sheep of 25 years ago, the average size of the male sheep's horns is smaller. Scientists know for certain that the sheep's horns do not fall off, and the sheep do not lose and re-grow their horns. But something is happening so that the sheep's horns are smaller than they were 25 years ago.

For more information on this, read Evidence 1 in pairs.

Evidence 1: How have mountain sheep changed in the last 25 years?

In pairs, read Evidence 1.

Ram Mountain in Alberta, Canada, is home to a population of mountain sheep. Biologists from the University of Quebec have studied these mountain sheep for 25 years. They wanted to know if the population of mountain sheep was changing. Each year for 25 years, they captured 95% of the sheep population in June and measured each sheep's horn size. Each sheep was tagged with a colored plastic ear tag. Most sheep were first tagged at the age of 1, when they were still not adults. When adults were captured, their age was determined by counting the number of rings on their horns, because sheep add one ring every year.

Over 25 years of collecting data on the sheep, the biologists found that the average horn size of male sheep in the population became 25% to 30% smaller. For example, 4-year-old male sheep in 1980 had an average horn size of 27 inches, but 4-year-old male sheep in 2005 had an average horn size of 19 inches. Sheep at every age from 1 year old to 12 years old showed an average decrease in horn size from 1980 to 2005.

Evidence 1: How have mountain sheep changed in the last 25 years?

In pairs, summarize the main ideas in this reading.

Evidence 2 - 5

You have already read Evidence 1. Next, in groups, complete Evidence 2 through 5 on the computer. Make sure to answer all the questions in your pairs as you go through each piece of evidence.

Evidence 2: Horn Growth

Evidence 3: Trophy Hunting

Evidence 4: Offspring

Evidence 5: Hunter's Blog

Goal: Analyze Models

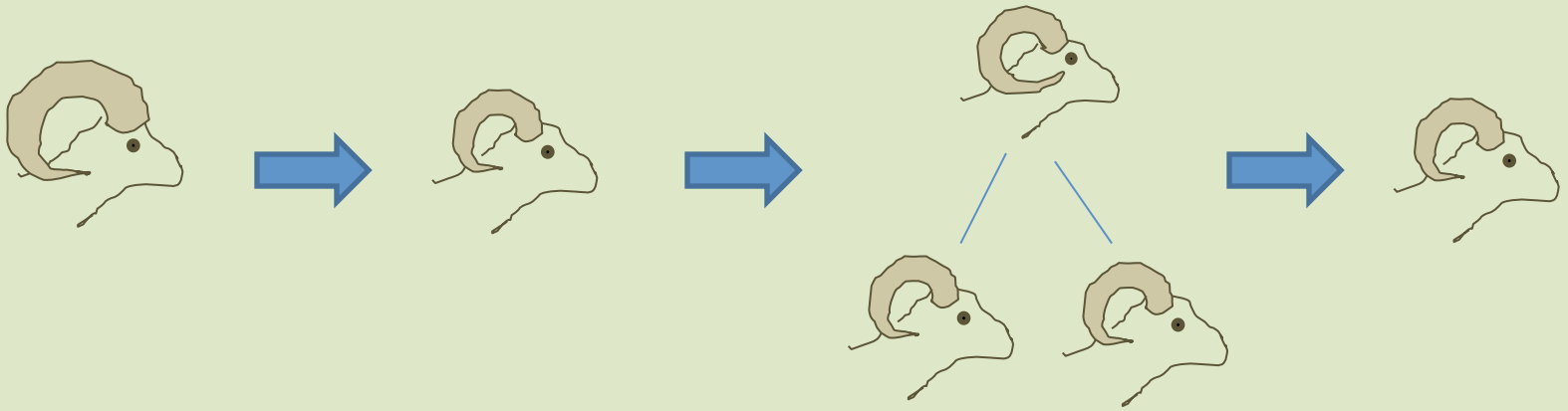
You will analyze and evaluate four different models that explain why the size of the male sheep's horns are smaller today than 25 years ago. You will use 5 pieces of evidence to evaluate the models and to choose the one that best explains the change in sheep horns.

With your group, complete the evidence diagram for each of the four models.

1. Look at the model carefully and discuss what it is showing.

2. Discuss the evidence you previously read and decide how well each piece of evidence supports that model.

MODEL A



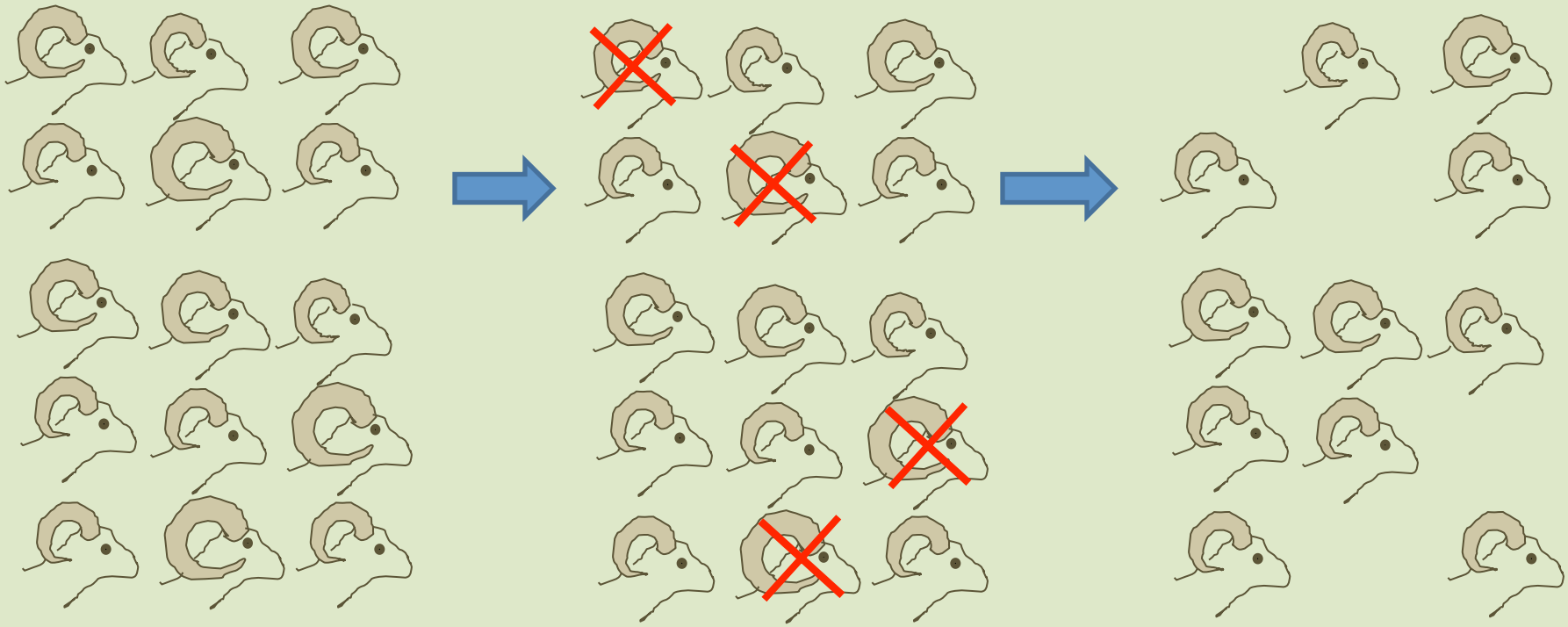
Male mountain sheep have big horns.

To hide from hunters the males make their horns smaller.

The males pass on the smaller horns to their offspring, who make their horns even smaller.

Now male mountain sheep have smaller horns.

MODEL B



The population of male sheep have many different horn sizes from big to small.

Hunters shoot the males with the biggest horns.

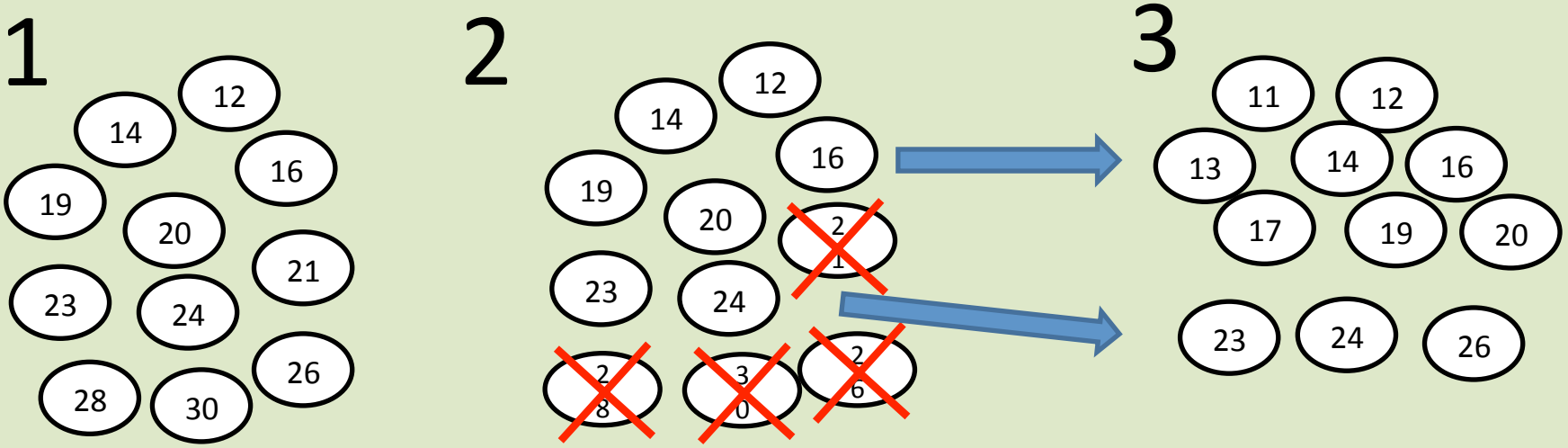
The males that are left have smaller horns.

KEY:

shows what happens next

shows which sheep were killed by hunters

MODEL C



The population of male sheep has many different horn sizes from big to small.

Hunters kill many of the sheep with bigger horns.

Sheep with smaller horns tend to have offspring with smaller horns. Sheep with bigger horns tend to have offspring with bigger horns. More sheep with little horns survived, so there are more offspring with smaller horns.

After several generations, there will be many more sheep with littler horns than bigger horns.

KEY:

20 shows a sheep with its horn size

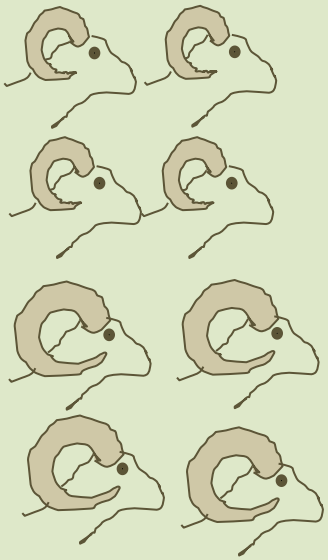
shows offspring

shows which sheep were killed

1, 2, 3 shows steps in the process

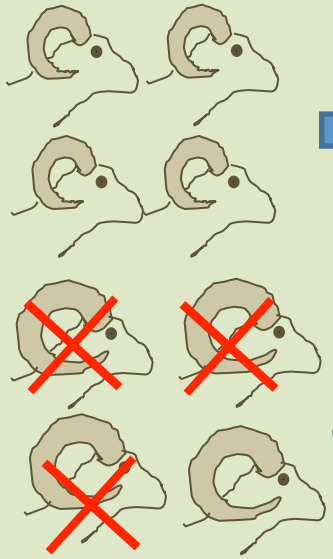
MODEL D

1



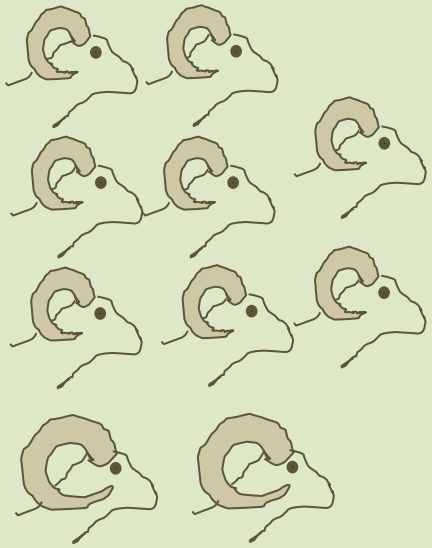
The population of male sheep has sheep with big horns and sheep with small horns.

2



Many of the sheep with big horns die.

3



The sheep with little horns have offspring with little horns. The sheep with big horns have offspring with big horns. More sheep with little horns survived, so there are more offspring with smaller horns.

After several generations, there will be many more sheep with little horns than big horns.

KEY:

 shows offspring of sheep with little horns and sheep with big horns

 shows which sheep were killed

1, 2, 3 shows steps in the process

Which Model is Better?

In pairs, discuss the following question:

Based on the evidence, which model is best explains why sheep horns have decreased in size?
Provide reasons during your discussion.

Then, Individually, write which model is best and why.
Look at the last page for further directions.

Mountain Sheep Evidence

Evidence 2: Horn Growth

Evidence 3: Trophy Hunting

Evidence 4: Offspring

Evidence 5: Hunter's Blog

Click on each piece of evidence.

Evidence 2: Horn Growth

The Colorado Division of Wildlife tags sheep and then follows these sheep from year to year. They catch the sheep each year to measure the horn length and other things, and then they let the sheep go. They studied changes in horn length of 298 male sheep during the last 8 years. The table on the next page shows the data from a male sheep that was exactly average.

HOME

NEXT

Evidence 2: Horn Growth

The horn length of an average sheep:

Age	Horn Length (inches)
2	10
3	15
4	19
5	21
6	23
7	24
8	25
9	26

The 298 male sheep varied in how much their horns grew each year. But every single male sheep's horns got bigger each year. No sheep lost its horns, and no sheep's horns ever got smaller.

What should the Colorado Division of Wildlife conclude from the data they collected?

BACK

HOME

Evidence 3: Trophy Hunting

Mountain sheep hunters hunt for the largest horns they can find to hang on their walls. They want to be able to display the horns as trophies for others to see. Hunters often wait all day, even several days, until they find a mountain sheep with the largest horns. In a 2009 survey of mountain sheep hunters by scientists at the University of Montana, 100% said that they strongly preferred to shoot sheep with big horns. 85% said that they did not ever shoot at sheep with smaller horns.

As a group, take turns asking 1 question to your group members about this evidence. Make sure you all understand the evidence before moving on to the next page.

HOME

NEXT

Evidence 3: Trophy Hunting

Male mountain sheep are hunted at the ages of 5 or older. Only males can be hunted.

A study by biologists from the University of Quebec showed about most of the male sheep killed by hunters are 5, 6, or 7 years old. The hunters kill sheep with big horns.

The biologists also found that male sheep produce more offspring when they are 7, 8, and 9 than when they are younger. This is because as the males get older and stronger, they gather a larger number of females in their herds, and so they have more offspring with the many females in their herd.

As a group, take turns asking 1 question to your group members about this evidence. Make sure you all understand the evidence before moving on to Evidence 4.

BACK

HOME

Evidence 4: Offspring

Scientists wanted to know if mountain sheep with big horns produced offspring with big horns, on average.

Scientists studied 370 sheep in Montana and Wyoming.
Here is what they found:

On average, male sheep with bigger horns have offspring with bigger horns. There is variation in the horn size of their offspring, but the average horn size of their offspring is bigger.

On average, male sheep with smaller horns have offspring with smaller horns. There is variation in the horn size of their offspring, but the average horn size of their offspring is smaller.

As a group, take turns asking 1 question to your group members about this evidence. Make sure you all understand the evidence before moving on to Evidence 5.

HOME

The Hunter's Blog

By Jack Wilson

September 30, 2011: 9:15 pm – Arriving at Powell, Wyoming

I just arrived to the lodge I am staying at with 8 of my friends for our big hunting trip in Powell. Northwestern Wyoming has the largest concentration of Mountain Sheep in the lower 48 states. I have been coming up here for the past 20 years with about a dozen of my friends. We hunt mountain sheep for trophy, meaning for their horns.

I posted a picture of what the horns look like. Typically we each come home with a trophy piece, but recently we've had trouble finding sheep with big horns. Maybe this year will be *the year*. I will post more each day about our trip. Until then, good night.

HOME NEXT BLOG POST

The Hunter's Blog

By Jack Wilson

October 1, 2011 8:14pm – Day 1

Today was not a very good day for us.
We were out for about 7 hours today, and only a few mountain sheep crossed our path.
Many of those were females, which we don't shoot.
I posted a picture so you can see what females look like.

We did see a few males, but their horns were pretty small, though not as small as the females' horns.

BACK NEXT BLOG POST

The Hunter's Blog

By Jack Wilson

October 2, 2011: 9:37 pm – Day 2

Day 2 was just as bad as Day 1. This time we did see plenty of male mountain sheep, but their horns were small in size (top picture). Horns too small for trophies. This year was not a success for me or any of my friends. I am not sure what is going on. Maybe we came too late in the hunting season, and all of the male sheep with the really big horns are gone. I remember when I first started hunting there were so many mountain sheep with really big horns. Now they are really hard to find. The bottom picture shows a photo I took in 1986 while I was hunting. I guess I might need to find something else to hunt. We are heading home in the morning. Good night.

BACK NEXT

Evidence 5: Hunter's Blog

You have now read all of Evidence 5, the 3 blog posts written by the hunter.

As a group, take turns asking 1 question to your group members about this evidence. Make sure you all understand the evidence presented.

BACK HOME

Developing a General Natural Selection Model

Developing a General Model

- We have studied 3 cases in detail.
  - Antibiotic resistance
  - Impact of the number of flagella on bacterial survival
  - Changes in mountain sheep horn size over time
- Now we'll use what we have learned to develop a general model of natural selection.

Natural Selection

- The evolutionary models that we have been developing are called "natural selection" models. Natural selection means that some organisms survive and have more offspring because they have a trait that is advantageous in that particular environment. For example:
  - Mountain sheep with small horns survive better and have more offspring when hunters are around because hunters don't shoot them. We say that sheep with small horns are naturally selected (or selected for), because in their environment, they are the ones that survive better and have offspring.
  - *B. megaterium* that are resistant to streptomycin are better able to survive in the presence of streptomycin and have offspring that are also resistant and able to survive in that environment. We say that resistant *B. megaterium* are naturally selected (or selected for), because in this environment, they are the ones that survive and have more offspring.
- We are going to make a general model of natural selection.

What parts do our models have in common?

- Look at your *B. megaterium,* Netlogo, and Mountain Sheep materials.
- Discuss in your groups:
  - What parts of these models are similar or the same?
  - What parts of these models are different?
- Write down everything you can find that is common to the three models.

Words that may be helpful as you think about what the models have in common

- A population is a collection of organisms in a species living in a specific area.
  - Example: All the moths living in forests in New England are a population of moths.
  - Example: All the Red-Bellied Black Snakes living in Australia are a population of Red-Bellied Black Snakes.
- An individual is one organism in a population.
  - An individual moth is one moth.
  - An individual Red-Bellied Black Snake is one snake.

Words that may be helpful as you think about what the models have in common

- Traits. Here are some examples:
  - Wing color in moths.
  - Weight of moths.
  - Ear size of rabbits.
  - Hair color of humans.
- Variations of a trait. Here are some examples:
  - Wing color in moths is the trait: one variation of the trait is dark; another variation is light.
  - Weight of moths: One variation of the trait is 3 grams; another variation of the trait is 2 grams.
  - Ear size of rabbits: One variation of the trait is large; another variation of the trait is short.
  - Hair color of humans: One variation of the trait is blonde; another variation is brown; another variation is black; another is red.

Words that may be helpful as you think about what the models have in common

- The advantageous variation of a trait is the version of a trait that helps individuals in a particular environment.
  - Example: Lighter wing color is an advantageous version of the wing color trait for moths when the trees have light bark.
  - Example: Small heads are an advantage trait for snakes when there are poisonous toads around, because then they cannot eat the toads and die from the poison.

Words that may be helpful as you think about what the models have in common

- An environmental change is a change in the environment.
  - If hunters start hunting in an area, that is an environmental change.
  - If tadpoles are living in a quiet pond, and dragonfly larvae move to the pond, that is an environmental change.
  - If the color of trees that moths rest on changes, that is an environmental change.

Useful Words

- As you think about what the models have in common, these words may be helpful:
  - Population
  - Individual
  - Trait
  - Variation of a trait
  - Advantageous variation of a trait
  - Environmental change

Sharing ideas

- What characteristics do the three different models have in common?

Model of Natural Selection

- We can take all the things that the models have in common to make a general model of what happens.

- With your groups, make a general model of natural selection. Be sure to use the appropriate terminology along with some type of visual representation so that others can look at your model and understand what happens in natural selection.

Sharing ideas

- Look at the models created by the other groups.
- Return to your model and make changes, if needed.
- Once you are happy, take a picture of your groups' model for your records.

Describing the Model of Natural Selection

- Now work in groups to describe in a step-by-step fashion how natural selection occurs. You should write your description on the handout provided or in your notes.

KEY:

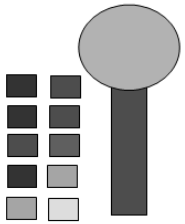
shows a tree in the woods

shows the population of moths

shows which moths were killed

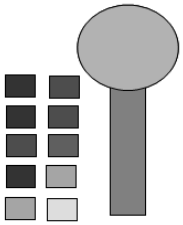
1, 2, 3... shows steps in the process

1



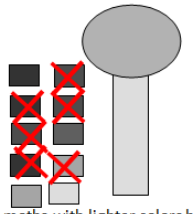
The starting population of moths includes moths with many colors, but mostly dark. They live on dark tree trunks.

2



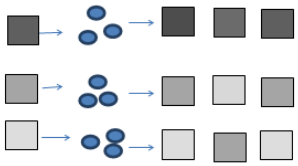
There is an environmental change. Tree bark gets lighter because of less pollution.

3



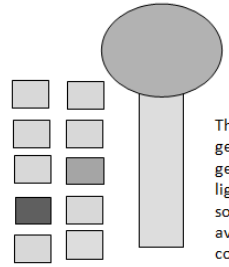
Now moths with lighter colors have an advantage. Birds see the darker moths that stand out on the light trees and eat them. More of the light colored moths survive.

4



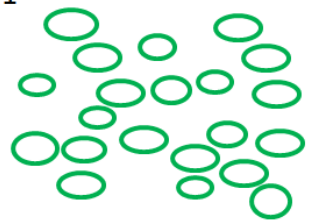
Surviving moths mate, lay eggs, and reproduce. Moths with lighter wings tend to have offspring with lighter wings. More moths with lighter wings survive. In the next generation, there are more offspring with lighter wings.

5



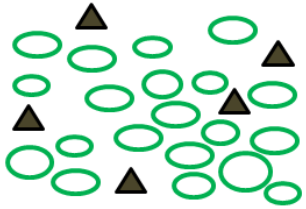
This continues for many generations. After many generations, the moths are lighter in color. There is still some variation, but on average the moths are light colored.

1



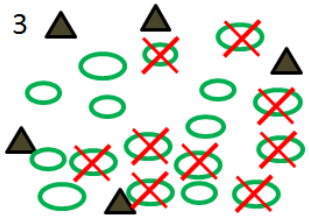
The starting population of snakes varies in the trait "head size." There are more snakes with larger heads.

2



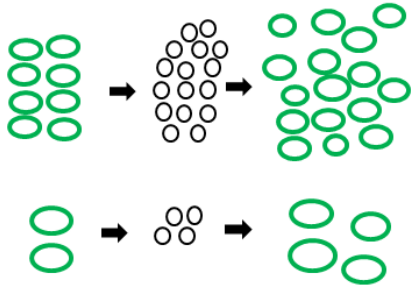
There is an environmental change. Large poisonous toads are introduced to the population.

3



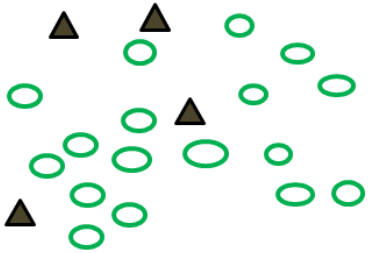
Snakes with smaller heads cannot easily swallow the poisonous toads, so they are safe. They survive. More snakes with larger heads die because they can eat the poisonous toads.

4



The snakes that survive reproduce and the next generation has more snakes with smaller heads than before.

5



This continues for many generations. After many generations, there is still some variation in the population, but all of the snakes have smaller heads, on average.

Key

Snakes with varying head sizes

Poisonous toad

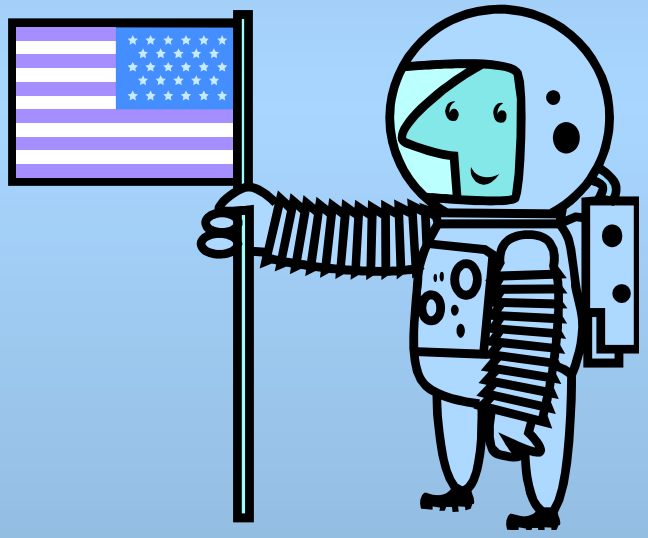
Shows snakes that die from eating poisonous toads

1, 2, 3... Steps

Persuasive Strategies

Claim

State your argument.



Example: I am going to try to convince you that chocolate is a healthy snack.

Big Names

Important people or experts can make your argument seem more convincing.

Example: Former U.S. president Bill Clinton thinks that junk food should be taken out of vending machines.

Logos

Facts, numbers, and information can be very convincing.

Example: A Snickers bar has 280 calories and 30 grams of sugar. That's not very healthy.

Pathos

Getting people to feel happy, sad, or angry can help your argument.

Example: Your donation might just get this puppy off the street and into a good home.

Ethos

If people believe and trust in you, you're more likely to persuade them.

Example: Believe me! I've been there before. I'm just like you.

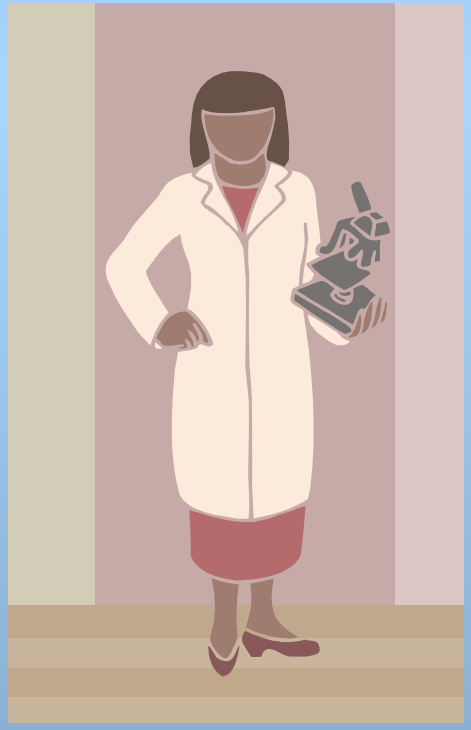
Kairos

Try to convince your audience that this issue is so important they must act now.

Example: This is a one-time offer. You can't get this price after today.

Research

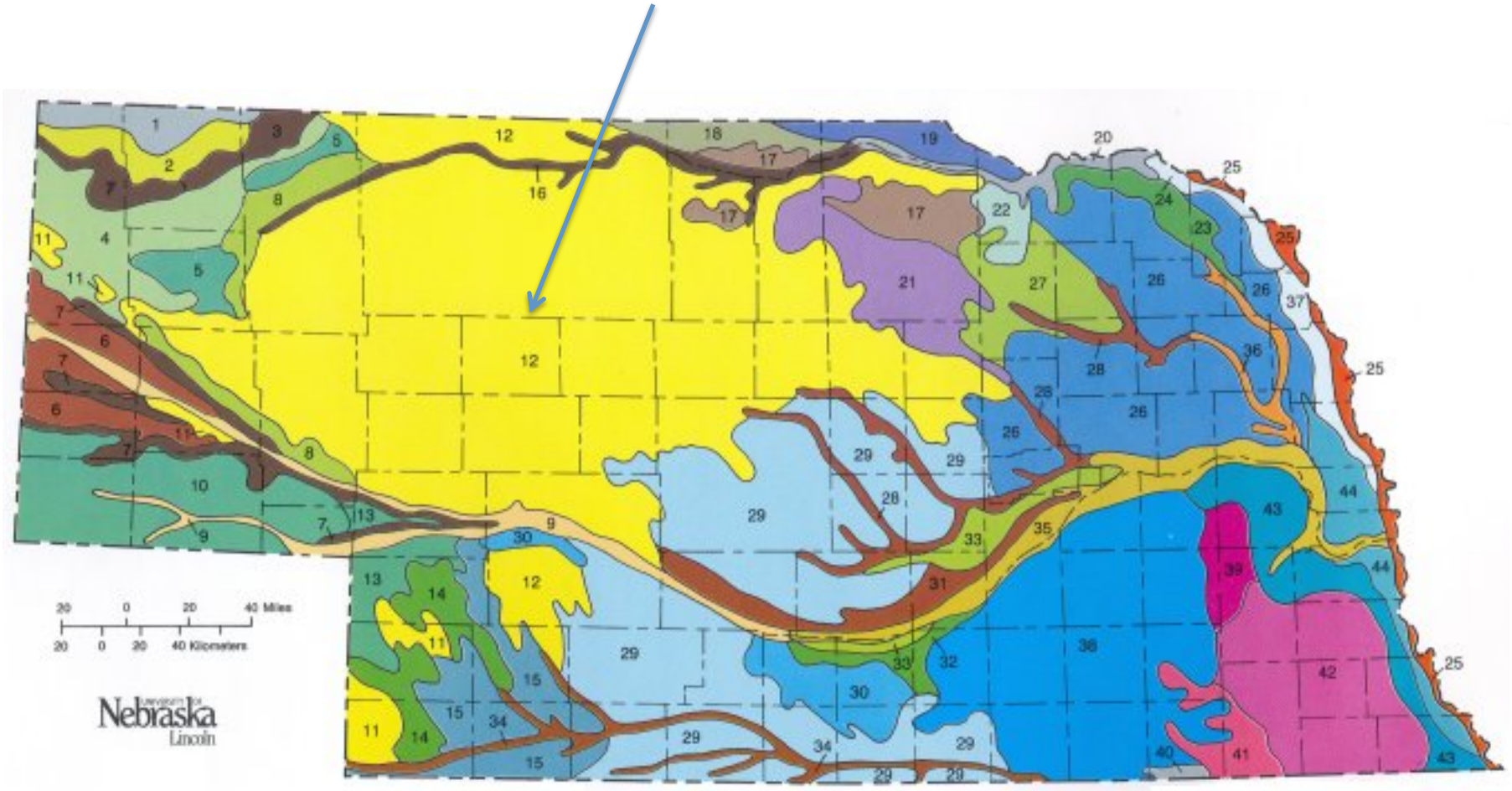
Using reliable research can help your argument seem convincing.



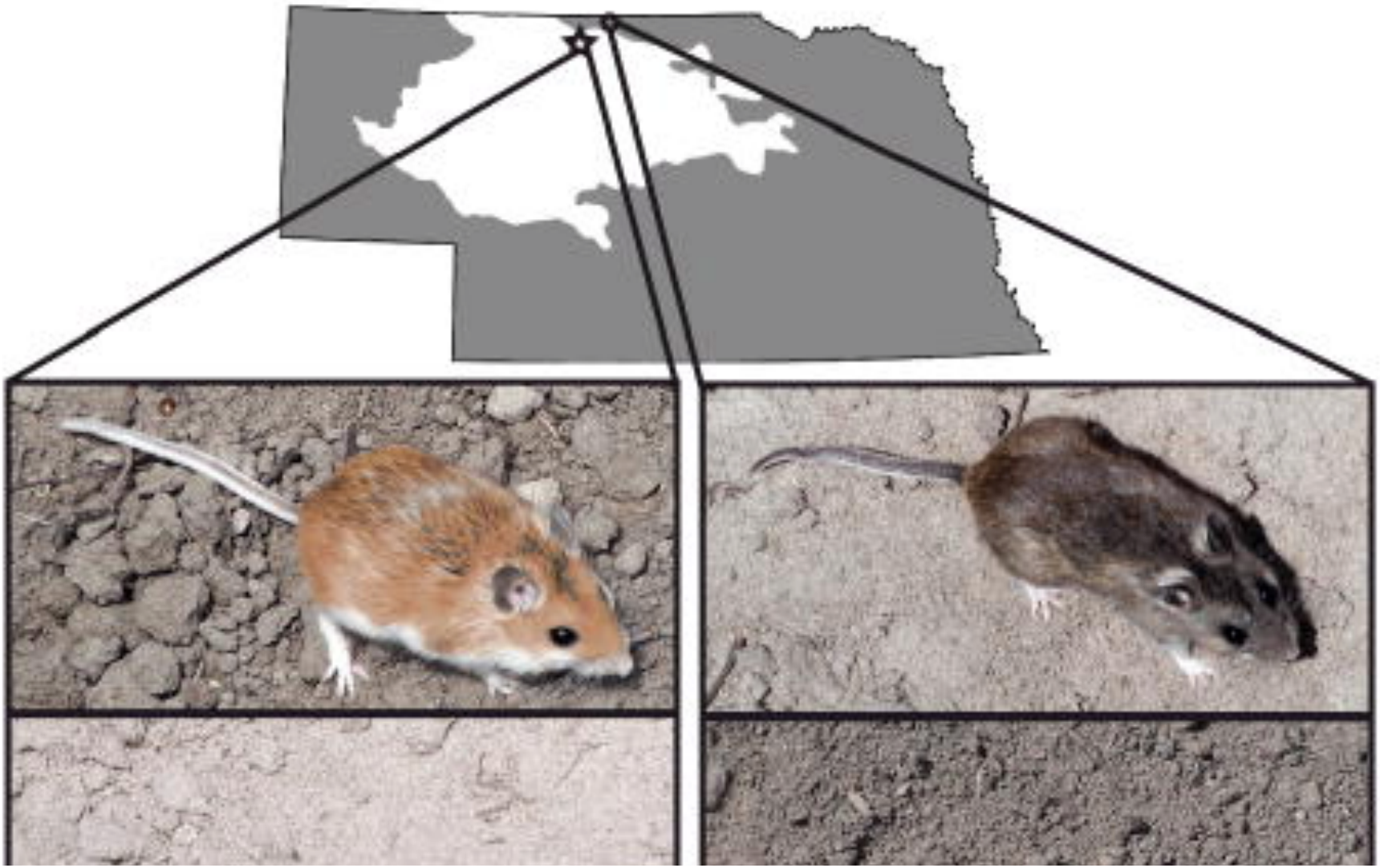
Example: A recent study found that students who watch TV during the week don't do as well in school.

Natural Selection In Action

Sandhills Region



Sandhills at Sunset



The Rest of the Story . . . .

It was on a short-cut through the hospital kitchens that Albert was first approached by a member of the Antibiotic Resistance.

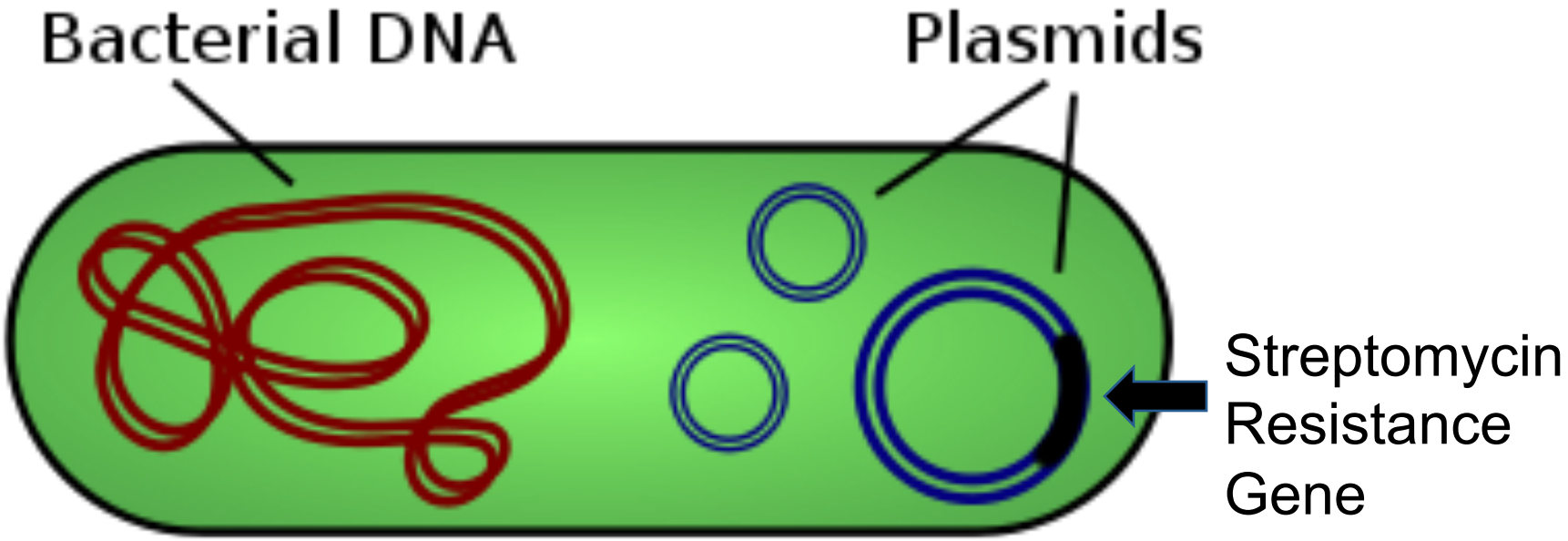
http://novabay.com/blog-post/growing-crisis-antibiotic-resistance-get-can-done

Quick Review

- How do bacteria, in general, become resistant to antibiotics?

Plasmids

- Plasmids have genes for antibiotic resistance.



Lateral Gene Transfer

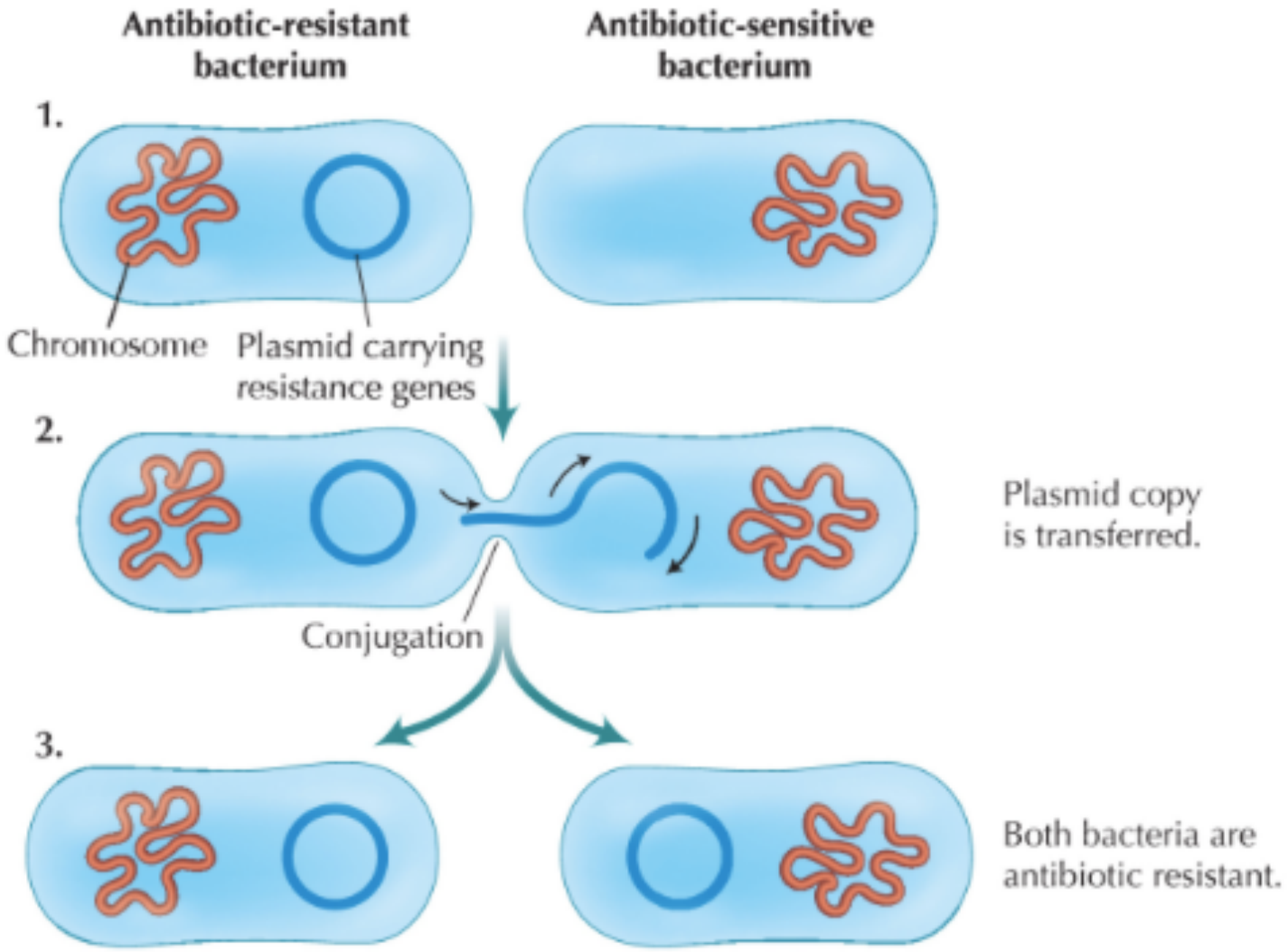


Image Source: http://www.evolution-textbook.org/content/free/figures/07_EVOW_Art/19_EVOW_CH07.jpg

Summary

- Plasmids reproduce and move into surrounding bacteria.
- Process is called **lateral gene transfer.**
- Lateral gene transfer can happen within the same species of bacteria.
- It can also happen BETWEEN species of bacteria.