Murder, Suicide, and Protection: Investigating Cyanide as a Weapon in History and the Natural World

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In this set of lessons, students will be introduced to natural selection by studying cyanide, a chemical with potentially lethal effects. Cyanide is best known as a suicide pill. Made infamous by its use in WWII in the suicides of Hitler and his closest companions, cyanide capsules are still used and portrayed in popular media (e.g., the television program "24") as a method of suicide. In the 1980's, tampered Tylenol laced with cyanide also caused the deaths of a handful of people in Chicago. Cyanide can kill when ingested or inhaled, though as a chemical weapon it is not as effective as others (such as mustard gas) which kill or incapacitate at much lower doses.

Cyanide is an intriguing chemical to study in biology for several reasons. First, while cyanide has whole-body effects (like death!), it acts on only one enzyme, cytochrome c oxidase, in the human body. This enzyme is located in the electron transport chain of mitochondria, organelles students know as eukaryotic cells' powerhouses. When cyanide inhibits this enzyme, aerobic cellular metabolism grinds to a halt, ATP production ceases, and tissue death begins. If exposure levels are high enough, death can occur in less than ten minutes.

Second, students may be familiar with cyanide's presence in the natural world, and if they aren't they will certainly be intrigued by learning that this highly toxic chemical is present in some of their favorite fruits. Most people know its not good to eat peach pits or apple seeds, though few could tell you that these fruits, and other stone fruits, have cyanide in their seeds. In fact, many plants have used cyanide as an effective defense mechanism against predation.

This set of lessons includes an introduction to cyanide in which students are presented with a fragmented story about the Goebbels children, who were murdered using cyanide in Hitler's bunker during the invasion of Berlin. Students then research the lethal chemical and teach their classmates about its chemistry, uses, mechanism of action, and sources. Students then work through a case study covering the basics of natural selection, evolution, and fitness which focuses on cyanide in two variants of white clover (adapted from a study published by the National Center for Case Study Teaching in Science, University at Buffalo, State University of New York).

These lessons are aligned with the South Carolina Science Standards.

Stage 1—Desired Results

Established Goals:

The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions (South Carolina Science Stardard B-1). The student will:

- 1.1 Generate hypotheses
- 1.4 Design scientific investigations that utilize controls, independent and dependent variables.
- 1.5 Organize and interpret data
- 1.6 Evaluate experimental results and hypotheses

The student will demonstrate an understanding of the flow of energy within and between living systems (SCSS B-3). The student will:

- 3.3 Recognize the structure of ATP and summarize its function

The student will demonstrate an understanding of biological evolution and the diversity of life (SCSS B-5). The student will:

- 5.1 Summarize the process of natural selection

Understandings:

Students will understand that . . .
ATP is required to power essential life functions
Cyanide disrupts cellular metabolism
The disruption of processes at the cellular level can cause whole-body disruption, even death
The prevalence of an organism in a specific environment is related to it's fitness
The length of the arms on a phylogenetic tree is related to the relationship between its organisms

Essential Questions:

What are some notable instances in which cyanide has been used by humans in the past?
Is cyanide an effective chemical weapon?
How and why are plants living in colder climates different from those living in warmer climates?
Why do some plants contain cyanide?
How have plants adapted to contain cyanide in response to their environment?
How does cyanide cause death?
Could cyanide affect anaerobic organisms?

Students will know . . .

The basic structure of ATP
The general mechanism by which cyanide prevents the formation of ATP (interfering with enzymes in the electron transport chain)
Specific vocabulary related to the unit, including:
Natural selection, fitness, artificial selection, adaptation, survival of the fittest, descent with modification, natural variation, evolution, common descent,

Students will be able to . . .
Explain the concept of fitness using clover as an example
Effectively search the internet for information by evaluating sources and refining searches
Read, understand, and synthesize data presented in figures and tables
Predict the distribution of organisms (clover) with different adaptations in specific habitats
Formulate hypotheses regarding the fitness of organisms with various adaptations in specific environments
Design experiments (including data collection) to test hypotheses, focusing on only one variable at a time
Synthesize and summarize knowledge gained about natural selection, adaptation, evolution, and variation from the clover case study

Stage 2—Assessment Evidence

Performance Tasks:

- Researching cyanide activity, discussion, and teaching. Students will demonstrate effective search techniques and research skills and will then, in groups, teach their classmates about an aspect of cyanide or cyanide poisoning.
- Exercises 1-10 from clover case study

Other Evidence:

- Gallery walk story/description, initial and revised
- Quiz including questions on cyanide's characteristics and effects (drawn from students' presentations on day 1), natural selection and evolution, and skills/information related to the case study

Stage 3—Learning Plan

Materials:
Gallery walk photos
Der Spiegel Article
Movie Der Untergang
Laptops with internet access
Library books containing information about cyanide
Cyanide research questions
Whiteboard and markers
Student sheets from case study
Case study introduction
Day 3 Homework
Natural Selection Powerpoint
Natural Selection Figures

Optional: examples of striped and plain white clover

Learning Activities:

Day One - "Hook" and Introduction to Cyanide

1. Begin class with a gallery walk of the last days in Hitler's bunker in Berlin, including Goebbel children's murder and Eva Braun's suicide, both by cyanide capsules (15 min.)
   a. Have students walk through the gallery of pictures and view them in order.
   b. Ask students to write a one paragraph story describing what they thing is happening.
2. Have students read an excerpt from an article on the murder/suicides from the German newspaper Der Spiegel. When students have finished, have them view the scene in which the Goebbel children are given cyanide from the movie Der Untergang .
3. Have students rewrite their description from part 1.b., drawing from information in the article/video.
4. Explain to students that they will be studying cyanide, the chemical used to murder the Goebbel children, Hitler, and his wife Eva Braun. Cyanide is often associated with capsules used in suicides like those of Hitler and his entourage, but it occurs in nature and students may encounter it in their everyday life. The class will spend the next ten minutes or so researching cyanide using laptops and relevant library books provided.
   a. Optional technology tutorial: If necessary, demonstrate effective internet search techniques, including refining searches for more specific, in depth information based on general sources (e.g. Wikipedia) using a laptop and projector.
   b. Divide students into groups of 3-4 and have each group get a laptop and several books. Every student should be actively researching and writing down key information, though if they are on task, up to two students may be working on the computer together.
5. After students have researched for 5-10 minutes, instruct them to get together and share what they found with their other group members. The group should summarize this information and answer one of the following question sets, assigned to their group by the teacher and given to them on a slip of paper:
   a. Cyanide's chemistry: List the chemical formulas for at least 3 cyanide compounds and describe the bonds that hold them together (hint: more than one type!). What ion do they all contain? List and briefly explain 3-4 uses of cyanide.
   b. Make a list of as many naturally occurring sources of cyanide as you can. What characteristics do these sources share? How are they different?
   c. Cyanide's effects 1: List and briefly explain the symptoms of cyanide poisoning. Define any words you don't know in your explanation (e.g., to explain a symptom of the condition hypothermia, one could say: "One symptom of hypothermia is tachycardia, or a faster than normal heartbeat). What is "cyanosis," and is it a symptom? Why/why not?
   d. Cyanide's effects 2: Explain the mechanism by which cyanide causes death first at the level of the entire organism and second at the level of the cell and its organelles.
   e. Cyanide's uses: Could cyanide be used effectively as a chemical weapon in a war? Explain why or why not. Might cyanide be more effective as a method of suicide? Explain.
6. Have each group select a representative to share their response to their question and instruct the other students to take notes from what each group says. If needed, take notes on the board to assist ELL students or to simply model note-taking methods.

a. After the last group has finished, write the following on the board: “Poison is in everything, and no thing is without poison. The dosage makes it either a poison or a remedy.”
b. Ask a student to rephrase the quote as he or she understands it (this saying, attributed to Paraclesus, is often rephrased as “The dose makes the poison”). Then, ask students if they know of any “good” things that in large amounts might be a poison.
c. Discuss several examples, including:
    i. Salt - excess sodium can cause hypertension or high blood pressure. Explain that our kidneys normally filter our blood to remove things that will pass out of our body in our urine, but when we overload our system with too much salt, our kidneys can’t keep up. Therefore, that salt remains in our blood.
        1. Draw a blood vessel on the board to review osmosis. Ask the students to think of the inside of the vessel like it’s a cell. Draw an equal amount of dots inside and outside the vessel. Ask students which direction water will move. Remove a few of the dots outside the blood vessel and ask the same question.
        2. Ask students how this movement of water causes high blood pressure.
    ii. If students need another example, explain the concept of hypervitaminosis and the difference between fat soluble and water soluble vitamins.

7. To close the lesson, explain that tomorrow the class will be learning how some plants use toxic substances like cyanide to help them survive. Have each student respond independently to the following prompt: Apple seeds along with cherry and peach pits contain a compound that when digested forms small amounts of cyanide, usually just enough to cause discomfort. Why might plants have adapted to do this?
    a. If time is short, assign the prompt as homework or reserve as a warm-up prompt for the next day.

Day Two - Plants, Cyanide, and Natural Selection

1. Ask volunteers to share their answers to yesterday's prompt about plants adapting to produce cyanide in their seeds. Challenge students to think about the advantages cyanide production might provide.
2. Explain that today the class will be working on a case study about plants that have cyanide in their leaves. Introduce the case study found here: http://www.sciencecases.org/clover/clover.asp
3. Students will be completing the case study's exercises in their lab notebooks. Before students receive the case study, have them set up their lab notebooks with a title, date, and the name of the person they'd like to work with (or the partner to which they are assigned). They will head each exercise with "Exercise ___," though the text of the exercise should not be copied down. Both partners are responsible for writing complete answers in their notebooks.
4. Introduce Part I of the case study, beginning with the microclimates in New York and the two clover variants (if possible, have physical examples of striped and plain clover in pots for students to observe). This introduction can be done as a type of charade/pictionary combination.
   a. Have a student read following introduction taken from the case study website referenced above. Instruct the student to read slowly and pause after every paragraph until told to go on. Teacher instructions are bolded.
      i. "White clover (Trifolium repens), a small perennial plant, is found throughout the world, and has two forms. One variant has entirely green leaves (plain) and the other has green leaves with a prominent white stripe (striped)." Walk around show students actual plants so they can compare the leaves.
      ii. "Both variants of white clover (plain and striped) are found along the coast of Long Island, New York. Most of Long Island is only a few feet above sea level. A series of low grass-covered hills separated by shallow depressions covers the area behind the oceanfront dunes. The shallow depressions reach to the water table, so they tend to be permanently moist year round and do not freeze in winter. Water drains away quickly from the low hills, which tend to dry out many times over the year and freeze in the winter. The habitat in the shallow depressions is more hospitable to mollusks (snails and slugs) that feed on clover. One type of clover is more common in shallow depressions while the other type is more likely to be found on low hills." Sketch the Long Island habitats on the board, drawing a drop of water in the depressions to indicate moisture and warmth and a snowflake on one of the hills to indicate that it freezes. Draw a slug or snail in a depression. Draw one large clover each on the hills and in the depressions, but inside it's leaves, write a question mark to indicate that it's type is unknown.
   b. Applaud the student reader and have him/her sit down. Explain to the class that at the end of the case, they will come back to New York and be asked to predict which type of white clover is most abundant in the microhabitats on Long Island. First, they will be comparing the clover types in two different states.

5. Give pairs of students a copy of the case study and have them complete Exercise 1 from the case study in pairs. When students have finished, briefly discuss the habitat differences between Minnesota and North Carolina.
6. Have student volunteers read aloud the introduction to Part II of the case study as a class.
    a. After a student has read the first paragraph, use the board to draw a representation of the cell and the location of the gene products required to produce active cyanide. Demonstrate by drawing how the enzyme could activate the cyanide-sugar complex.
    b. Have student volunteers read the second paragraph aloud. Ask students for an example of a perennial plant they know.
    c. Have students complete Exercise 2 with their partner.
7. Gather the class back together after giving students sufficient time to finish Exercise 2 (~10 minutes). Have students read aloud the first paragraph of Exercise 3 and explain the term "fitness."
    a. As a class, complete Exercise 3. Ask students to look back on the habitats they described in Exercise 1. What factors are important for plant fitness?
    b. Have students brainstorm a list of important ecological differences between North Carolina and Minnesota that might affect how fit the two variants are for that particular climate. What factors might make a plant grow, survive, and reproduce better (or worse) in each habitat?
8. Introduce Part III of the case study and review how to write a good hypothesis (must be testable, a statement and not a question, addresses only one variable at a time, must be able to prove it false, etc.)
    a. Have students work with their partner to complete Part III of the case study, including Exercises 4-7.
    b. Collect the case study to use for other classes and to use for Day 3.
9. If time permits, have student groups present their hypotheses and experimental design for each habitat. If there is not enough time for this, complete this activity tomorrow.

Day 3: Natural Selection and Evolution

1. Finish presenting student hypotheses and experimental designs from Part III of yesterday's case study.
2. Begin direct instruction on natural selection with Natural Selection powerpoint.
    a. Students should take their own notes, but will be provided with the figures from the powerpoint and a fill in the blank summary of what each represents.
    b. The final example figure of the evolution of a hairy caterpillar is only partially filled out. Students should complete this figure on their handout.
3. Explain to students that they now have more formal definitions for concepts they worked with yesterday, and they will be applying that knowledge to finish the case study.
    a. Pass out case study packets and instruct students to work on Part IV with their partner from yesterday's class. Remind them to write all answers in their lab notebook, and to give their work a new date.
    b. When students have finished, bring the class back together and discuss their answers to the following questions:
        i. What are examples of variation in the clover?
        ii. Refer back to Figure 1 showing the relative frequency of plain and striped clover in Minnesota and North Carolina. Explain why there is variation in the frequency of each type of white clover between each of these areas.
        iii. Adaptation in the white clover means that over time there is an increase in the frequency of particular traits that would help individuals in that population of white clover survive and reproduce in that particular habitat. What are examples of possible adaptations in the clover? Remember, adaptations are specific to a particular habitat.
        iv. Comparing the white clover populations in Minnesota and North Carolina, what would you need as evidence that evolution has occurred?
        v. Several factors may exert selection pressure on different traits in white clover in each habitat. What factor would you propose is exerting the strongest selection pressure on the production or non-production of CN (cyanide) in white clover in Minnesota? In North Carolina?
4. Explain that the class will now have time to study for a quiz on cyanide, the case study, and natural selection. Before they will get a chance to work with their partner to study, the class will be making a list of important terms and questions they should be able to answer.
    a. Start by having students brainstorm a list of questions, terms, and concepts from the first day when they learned about and researched cyanide. Circle in red any you find very important that will be on the quiz (cyanide's chemistry, sources, mechanism of action, etc.).
    b. Tell students that they should also be prepared to analyze charts and graphs similar to the ones they saw in the case study. If given information about habitats, they should also be able to make predictions about the environments in which organisms with certain characteristics will thrive.
    c. Finally, tell students that the most important information from today's lecture will be used in their homework tonight, which is to complete exercises 9 and 10 in their lab notebooks. Exercise 10 or something similar to it is very likely to turn up again in their quiz!

5. Pass out homework (exercises 9 and 10 from part V of the case study).

Sources:

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Alternative Articles:

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http://researchnews.osu.edu/archive/cassava.htm - Cassava and cyanide
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Murder in Hitler's Bunker

Who Really Poisoned the Goebbels Children?

By Georg Bönisch

To this day, the murder by poisoning of the six children of Nazi propaganda chief Joseph Goebbels remains a mystery. Newly discovered records show that a doctor confessed in the 1950s to having been an accomplice, but that the judges in the case let him go unpunished.

These are the last days of their lives, but the children don't know it. There is 12-year-old Helga, who has the eyes and dark hair of her father, Joseph Goebbels. There is Hilde, 11, who is more of a brunette; anyone looking at her quickly realizes that she is about to blossom into a true beauty. And then there are eight-year-old Holde, six-year-old Hedda and the youngest of the girls, four-year-old Heide.

H for Hitler. The name of each child evokes the name of the Führer, for whom Goebbels works as propaganda chief. The family's only son is named Helmut, a slightly languorous nine-year-old.

Berlin, the end of April 1945, the Reich Chancellery. Hitler's bunker, deep underground beneath the Chancellery, is a place of gray concrete, narrow passageways, iron doors and cold light. It isn't a welcoming place, particularly not for children who, only a few weeks earlier, were living a seemingly carefree and innocent life, playing with cats and dogs on a farm far away from Berlin.

Russian soldiers are only a few hundred meters away, and everyone in the bunker is urging the parents to finally take the children to a safe place. Hanna Reitsch, a celebrated German aviator, says: "My God, Mrs. Goebbels, the children cannot stay here, even if I have to fly in 20 times to get them out."

But the Goebbels remain unyielding.

"It is better for my children to die than to live in disgrace and humiliation," says their mother, Magda. Their father fears that Stalin could take the children to Moscow, where they would be brainwashed into becoming communists. "No, it's better that we take them along."

Unpunished Crime

On April 30, at about 3:30 p.m., Hitler shoots himself in the head, and his companion Eva Braun dies with him. The double suicide is a signal for the others. By the next day, the six Goebbels children are also dead. After receiving morphine injections to render them unconscious, they are poisoned with cyanide, a substance that causes rapid death by suffocation.

Six dead children, and yet the act was never punished. Astonishingly, no historian has ever truly delved into this tragic crime, which was part of the final act of the Third Reich. To this day, the episode remains the subject of speculation and misinterpretation.

However there was a remarkable judicial sequel in the late 1950s, involving a case that was heard by a regional appeals court in the western German city of Hamm. The case files are stored at the national archive in nearby Münster. They have remained unnoticed until now, even though they highlight the "leniency and questionable argumentation with which the courts addressed Nazi crimes at the time," says chief prosecutor Maik Wogersien, who recently stumbled upon the documents, more or less by accident. Wogersien is conducting research on precisely this subject at the Legal Academy of the State of North Rhine-Westphalia.

According to the documents, the judges who prosecuted the Goebbels case were former members of the Nazi Party, as was so often the case in trials dealing with Nazi crimes in the newly formed Federal Republic of Germany. For example, the judges managed to disregard a completed indictment for infanticide, using incorrect and possibly even illegal arguments. The defendant was acquitted.

The newly discovered records now make it possible, for the first time, to reconstruct what actually happened.

Fateful Moment

The man who is the focus of all the documents was Helmut Kunz, who was born in the southwestern town of Ettlingen in 1910. After studying law, he went on to obtain a doctorate in dental medicine, writing a doctoral thesis titled "Studies of Dental Caries in Schoolchildren as Related to Their Feeding in Infancy." In 1936 he opened a dental practice in Lucka, south of the eastern city of Leipzig. Kunz was also a member of the Sturm 10/48 unit of the SS.

When Hitler began the war, Kunz served as a medical officer in the SS's notorious Totenkopf (Death's Head) division. He was seriously wounded in 1941, and after his recovery he was transferred to the medical unit of the Waffen-SS, the SS's combat arm, in Berlin. In April 1945, at the rank of *Sturmbannführer*, Kunz was transferred again, this time to the Reich Chancellery. For Kunz, who a confidant of Hitler had described as having an "erect soldierly bearing," it was to become a fateful moment.

Orders from Hitler

It was April 22, and the Goebbels were ready. It was too dangerous for the family to remain in their apartment in Berlin's Hermann-Göring-Strasse, and so their suitcases were packed and the children were dressed and told to put on their coats and hats. It was also a final goodbye for Käthe Hübner, their governess, nicknamed "Hübi." "We're going to stay with the Führer in his bunker now," said little Helmut. "Are you coming with us?" The young woman stayed behind, looking on as Magda Goebbels voluntarily followed the Führer "into his hopeless situation."

Magda Goebbels became Kunz's first patient at the Reich Chancellery after she developed an abscess under a bridge in her lower jaw. Magda Goebbels saw herself as a model mother and a kind of first lady. Even Hitler addressed her respectfully as "madam." This status alone made Magda Goebbels, a woman who could be very gentle at times but at other times strident, into a person of authority.

In late April, she took Kunz aside and literally asked him to "help with the killing of her children," as the dentist would later testify. Kunz, however, claimed: "I refused and told her that I was simply incapable of doing it."

He told her that he had just lost his two daughters a few months earlier during an American air ride on Lucka, and that he couldn't do it "for that reason alone." His daughter Maike was five when she died in the wreckage, and the other daughter, Maren, was barely a year old.

But Magda Goebbels insisted and is believed to have said, a short time later, that it was "no longer a request" of hers, "but a direct order from Hitler," according to Kunz's recollection of what Goebbels said during the argument. "She asked me if it was sufficient that she was delivering the order, or whether I wished to speak with Hitler in person."

Kunz allegedly replied: "That's sufficient for me." He reportedly attempted to escape a short time later, to the nearby Hotel Adlon, where one of his fellow SS members was believed to have set up a sick bay. But Magda Goebbels apparently ordered him brought back, threatening that if her husband found out about his attempted escape he would be "a dead man."

'Don't Be Afraid'

May 1, 1945, in the evening. The daughters and the son were already in bed, but were not asleep yet. "Don't be afraid," their mother said. "The doctor is going to give you a shot now, one that all children and soldiers are getting." She left the room, and Kunz injected the morphine, "first into the two older girls, then the boy and then the other girls." Each child received a dose of 0.5 cc. It "took eight to 10 minutes."

When the children had fallen asleep, Magda Goebbels went into the room, the cyanide pills in her hand, as Kunz testified. She returned a few seconds later, weeping and distraught. "Doctor, I can't do it, you have to do it," she said. The dentist replied: "I can't do it either." "Then get Dr. Stumpfegger," she said. Ludwig Stumpfegger, who was slightly younger than Kunz, had been one of SS chief Heinrich Himmler's personal doctors.

A week later, Russian coroners performed autopsies on the bodies of the children and concluded that their deaths had "occurred as a result of poisoning with cyanide compounds." The Goebbels themselves had committed suicide outside the bunker, and Stumpfegger died while attempting to break through the Russian lines in Berlin. Kunz, however, survived.

Cyanide Research Questions

Cut between the questions below and pass out to each group of students.

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1. Cyanide's chemistry: List the chemical formulas for at least 3 cyanide compounds and describe the bonds that hold them together (hint: more than one type!). What ion do they all contain? List and briefly explain 3-4 uses of cyanide.

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2. Cyanide in nature: Make a list of as many naturally occurring sources of cyanide as you can. What characteristics do these sources share? How are they different?

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3. Cyanide's effects 1: List and briefly explain the symptoms of cyanide poisoning. Define any words you don't know in your explanation (e.g., to explain a symptom of the condition hypothermia, one could say: "One symptom of hypothermia is tachycardia, or a faster than normal heartbeat). What is "cyanosis," and is it a symptom? Why/why not?

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4. Cyanide's effects 2: Explain the mechanism by which cyanide causes death first at the level of the entire organism and second at the level of the cell and its organelles.

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5. Cyanide's uses: Could cyanide be used effectively as a chemical weapon in a war? Explain why or why not. Might cyanide be more effective as a method of suicide? Explain.

Student-read introduction to clover case study:

White clover (Trifolium repens), a small perennial plant, is found throughout the world, and has two forms. One variant has entirely green leaves (plain) and the other has green leaves with a prominent white stripe (striped).

Both variants of white clover (plain and striped) are found along the coast of Long Island, New York. Most of Long Island is only a few feet above sea level. A series of low grass-covered hills separated by shallow depressions covers the area behind the oceanfront dunes. The shallow depressions reach to the water table, so they tend to be permanently moist year round and do not freeze in winter. Water drains away quickly from the low hills, which tend to dry out many times over the year and freeze in the winter. The habitat in the shallow depressions is more hospitable to molluscs (snails and slugs) that feed on clover. One type of clover is more common in shallow depressions while the other type is more likely to be found on low hills.

Lookin' over a White-Striped Clover: A Case Study in Natural Selection*

<u>PART I:</u> Write all answers in your lab notebook

Figure 1 - Relative frequency of clover variants in MN, NC

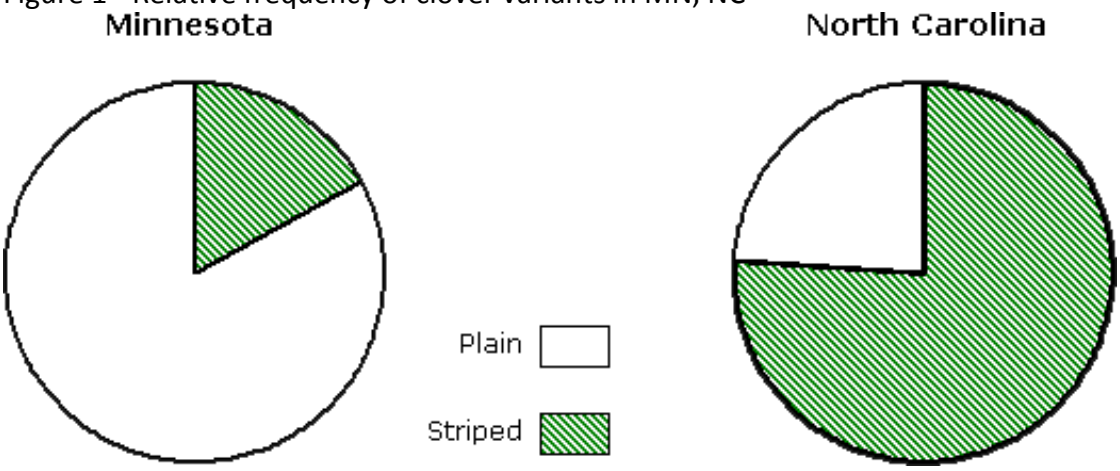


Table 1 - Habitat information for MN, NC

	Minnesota	North Carolina
Latitude	43–49° N	34–36° N
Mean elevation	0.365 km	0.213 km
Ave. monthly temp. range	−19.4° to 28.6° C	−2.6° to 31.3° C
High temperature	45.6° C	43.3° C
Low temperature	−51° C	−37° C
Mean # days with high above 32° C*	14	38
Mean # of days with low below 0° C*	154	75
Ave. yearly precipitation	66–76 cm	107–117 cm
Presence of herbivores (mollusks such as snails, slugs)	smaller population, not present in winter	larger, more active pop., present all year

From Netstate.com and NOAA.*Data for capitol cities (St. Paul, MN; Raleigh, NC).

Exercise 1 - Complete with partner

A habitat is defined as the place and conditions under which an organism lives. This includes physical factors such as temperature, soil type, availability of nutrients, and availability of moisture as well as biological factors such as presence of herbivores, competitors for nutrients, and pathogens. Using the information in Table 1, briefly summarize the habitat features for white clover in each state.

<u>Part II:</u>

Some variants of white clover produce cyanide (CN), which is a powerful poison. Two gene products are required to produce active cyanide. One gene encodes an inactive cyanide-sugar complex that is stored in the plant cell's cytoplasm. The other gene encodes an enzyme that cleaves the sugar to activate the cyanide. This enzyme is stored in the cell wall. In general, striped clover contains cyanide; plain clover does not.

In consistent freezing temperatures, plant cell membranes (surrounding organelles and the cell itself) can burst. This is why the parts of plants above ground die back in colder climates. Root cells, however, are less likely to burst because they are underground and often store sugars, which protect the cell from freezing (just like antifreeze). This allows perennial plants to survive and grow again in the spring. Like the damage caused by freezing, herbivores can also damage plant cells. In the process of eating a leaf, herbivores destroy the membranes and organelles of the cells that make up the leaf.

Exercise 2 - Complete with partner

1. Why do you think the two gene products are stored in different parts of the cell?
2. Suggest at least two ways these products might come together to make active CN in nature.
3. Suggest a reason that clover may produce cyanide. That is, what advantage does a plant gain by producing cyanide? Also suggest a possible disadvantage of producing cyanide. Or might there be no advantage?
4. It takes energy for an organism to produce a particular structure such as a stripe on a clover leaf that is otherwise plain. Why might cyanide-producing clover produce striped leaves?
5. To explore this idea a little further, consider the following results of the hypothetical experiments shown below in Table 2. In each situation, snails that have been taken from a wild habitat where both types of clover are present were put in a Petri dish containing varying types of clover. Make an interpretation of the snails' response to 1-4 in the table.

Table 2 - Hypothetical Experiment Results

Clover presented to snails	Snail response
1. plain green leaves	eaten
2. striped leaves and plain leaves	plain leaves eaten
3. striped leaves	not eaten
4. plain leaves painted with white stripe	not eaten

Exercise 3 - Complete as a class

To understand why cyanide producing/striped clover is found at a higher frequency in North Carolina than in Minnesota, you must consider the "fitness" of each variant in the different habitats available in the two states.

Fitness is determined by the ability of an organism to survive, grow, and reproduce in a particular habitat. You have probably heard the term "survival of the fittest," but if an organism is not able to also

grow and reproduce, it will not be able to pass any of its alleles (genetic information) on to its offspring. An organism that has high fitness does well in its habitat and passes those favorable alleles onto its offspring when it reproduces.

Go back and review the habitats you described in Exercise 1 and think about the factors that would be important for plant fitness. Then list the ecological differences between North Carolina and Minnesota that might affect the fitness of each variant. In other words which factors might increase plant growth, survival, and reproduction in each habitat, and which factors might inhibit them?

Part III - Complete with partner
Now that you have considered the different habitats in which the white clover is found and the factors affecting fitness in clover, you will develop hypotheses to explain the observed distribution of plain and striped clover. A hypothesis is a tentative answer to a well-framed question. This means that one has developed an explanation of an event based on preliminary data, observations, and perhaps the work of other scientists. Scientists use observations and data to develop and justify their hypotheses. A hypothesis is presented as a statement, not a question, and must be both testable (there must be some way to test if it is valid) and falsifiable (it must be possible to show that an incorrect hypothesis is false).

Exercise 4
Based on the data presented above and the differences in habitat between Minnesota and North Carolina, propose a hypothesis to explain each of the following: a) the higher frequency of plain clover in Minnesota, and b) the higher frequency of cyanide producing/striped clover in North Carolina. Justify the reasoning leading to each of your hypotheses. Be specific in terms of which variables (conditions) affect the frequency of each type of clover in each habitat. Remember to write your hypotheses as statements, not as questions.

Exercise 5
Are your hypotheses the same for the different habitats? Explain why individuals or populations from the same species may show different traits in different habitats. Use the term “selection pressure” in your explanation. Selection pressure refers to the influence a particular factor has on the ability of an organism to survive and reproduce.

Exercise 6
Once a scientist has formed a hypothesis, the next step is to test it with observations or experiments. Experiments should test only one variable at a time, and keep as many other factors as possible constant (which doesn’t mean “unchanging,” but only that they are the same for all experimental groups). Design experiments to test at least one hypothesis for each habitat.

Exercise 7
For each of the experiments you proposed in Exercise 6, describe data that would support your hypothesis and data that would falsify your hypothesis.

Part IV: Complete with Partner

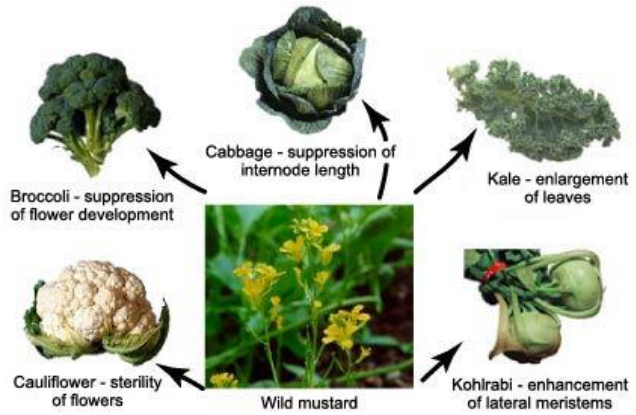
Exercise 8
1. What are examples of variation in the clover?

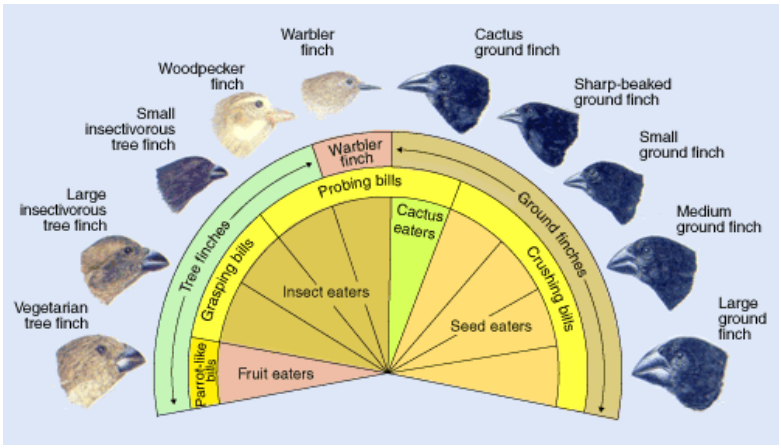
2. Refer back to Figure 1 showing the relative frequency of plain and striped clover in Minnesota and North Carolina. Explain why there is variation in the frequency of each type of white clover between each of these areas.
3. Adaptation in the white clover means that over time there is an increase in the frequency of particular traits that would help individuals in that population of white clover survive and reproduce in that particular habitat. What are examples of possible adaptations in the clover? Remember, adaptations are specific to a particular habitat.
4. Comparing the white clover populations in Minnesota and North Carolina, what would you need as evidence that evolution has occurred?
5. Several factors may exert selection pressure on different traits in white clover in each habitat. What factor would you propose is exerting the strongest selection pressure on the production or non-production of CN (cyanide) in white clover in Minnesota? In North Carolina?

*Materials taken from Susan Evarts, Alison Krufka, and Chester Wilson. This case study was published by the National Center for Case Study Teaching in Science, University at Buffalo, State University of New York.

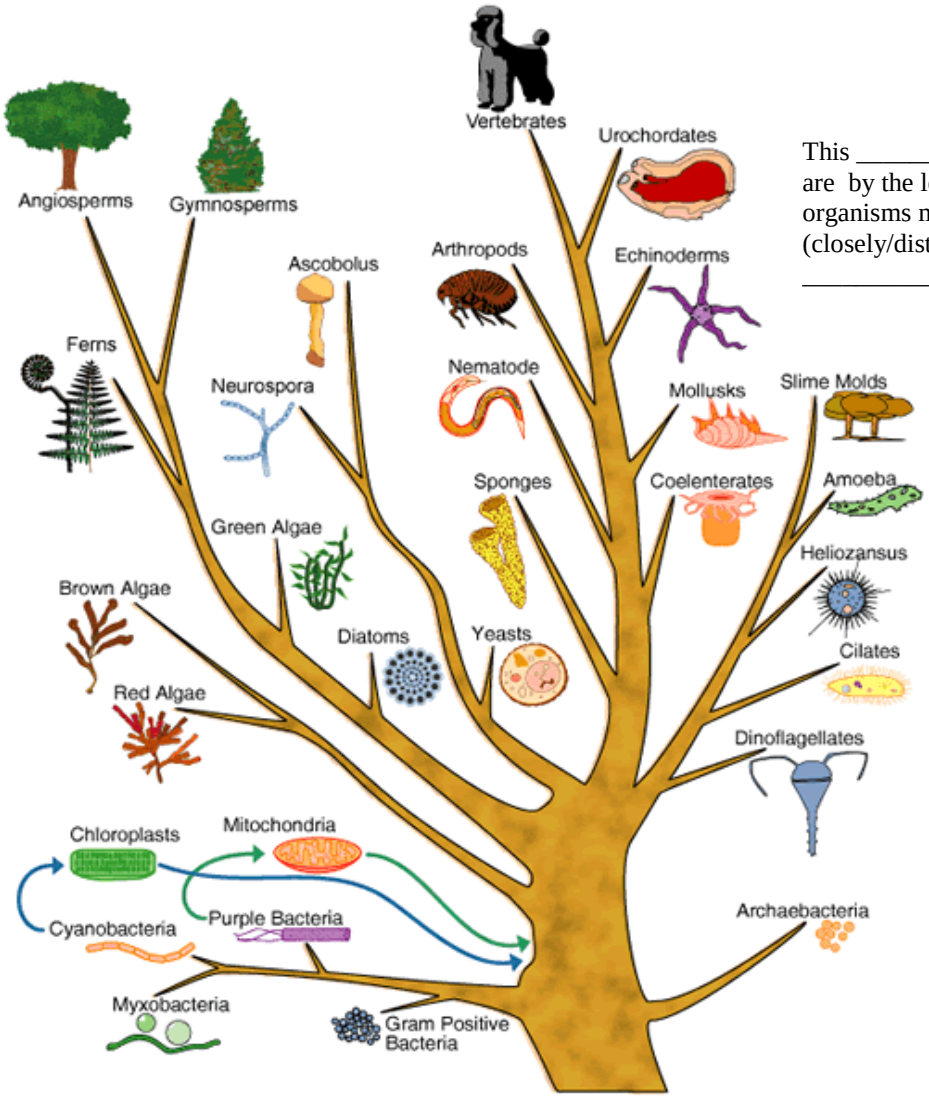
Natural Selection Figures

Name: _____
Date: _____



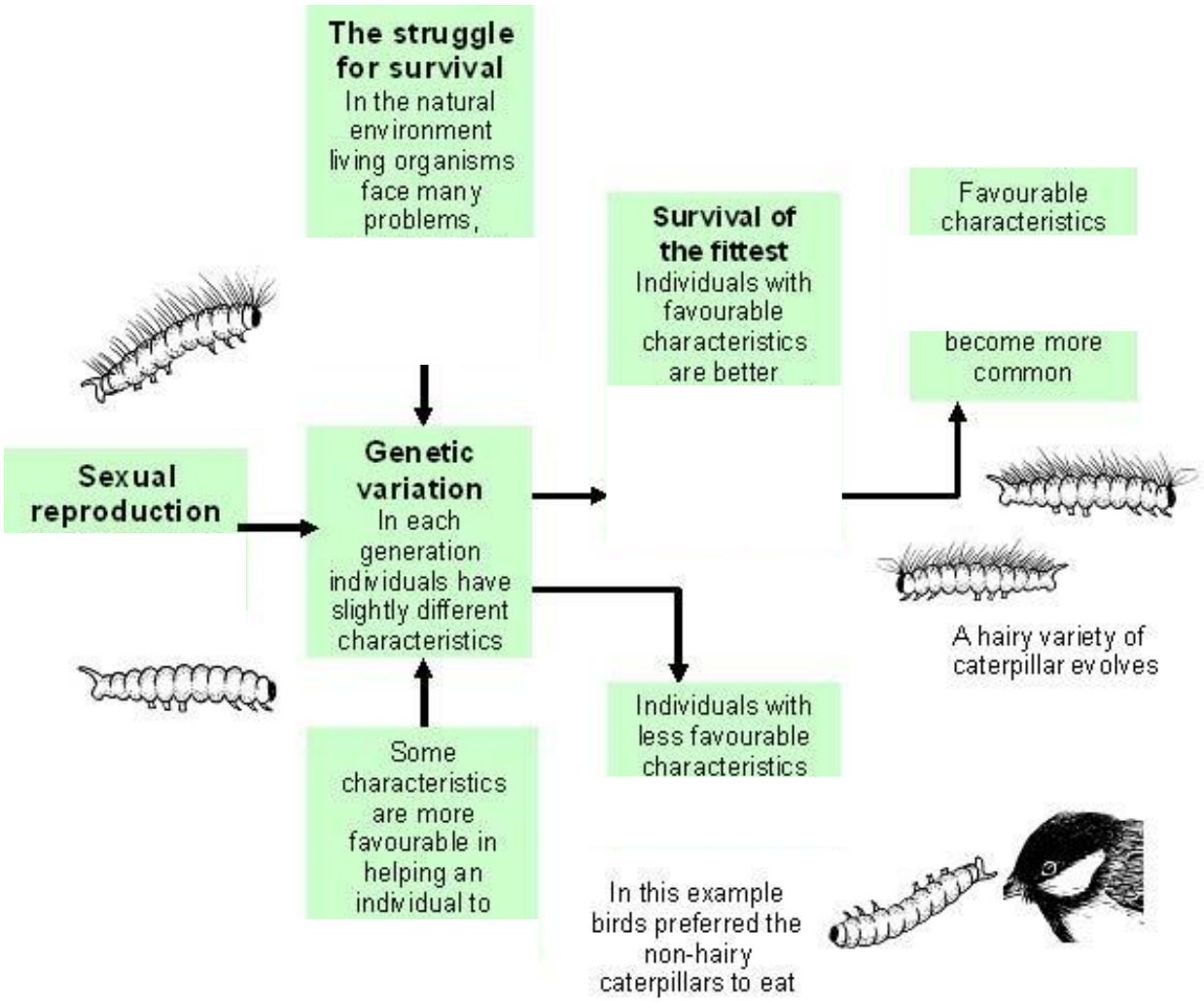


The development by humans of broccoli and it's other veggie friends is an example of _____ _____.



This _____ tree shows how related species are by the length of its arms. A long distance between organisms means they are _____ (closely/distantly) related. A short distance means they are _____ (closely/distantly) related.

Name: _____
Date: _____



Homework:

Complete the following exercises individually in your lab notebook. Answer all questions completely and thoroughly, paying special attention to Exercise 10 question 2.

Exercise 9

Based on your understanding of the clover case and the definitions provided above, which of the following statements are true? Explain *why each of the correct statements is true* or *correct each of the false statements* to produce a true statement.

1. Natural selection can fully be explained by the phrase "survival of the fittest."
2. Variation is necessary for natural selection to occur.
3. Adaptation is defined with respect to local environmental conditions (e.g., heat, cold, rainfall, competitors, herbivores).
4. Natural selection acts on populations, not individuals.

Exercise 10

1. Predict which variant of white clover would be most frequent in each of the microhabitats on Long Island (refer to Part I).
2. Write a paragraph that describes the distribution of clover in the microclimates of Long Island using the terms *variation, adaptation, natural selection,* and *evolution*. Be sure to fully describe each of these terms in your detailed paragraph.

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Gallery Walk

The following are the pictures, in order, for the gallery walk. The first few photos have short captions to help students put them in context. Mounting the photos on colored construction paper will help students differentiate between the invading Soviet army and images related to Hitler's bunker.

The Goebbels Family; Berlin, Germany; circa WWII

Soviet Army (aka the "red" army); just outside Berlin

Adolf Hitler, Berlin

Hitler's Bunker

RISE

RISE