

# Supplemental Material

*CBE—Life Sciences Education*

Tise *et al.*

## Appendix A

### Activity 1

#### Creating Analogies

Worksheets like this one will help you learn at a deep level so that you will be able to *use and apply* what you learn.

Your brain is a model builder. When it tries to comprehend something, it creates a model for how things should work. This model is informed by experiences, prior knowledge, new information, and your own world view. The concepts and connections between concepts that make up our models represent knowledge. They are what we know. Sometimes, however, these models can be incomplete or incorrect. In order to build accurate and complete knowledge models, we have to generate meaning from new information. Meaning is generated by creating two types of relationships:

1. Relationships between your own knowledge/experience and the new information
- and
2. Relationships among the parts of the new information.

We can generate these two types of relationships in several ways, but one very effective and research-supported strategy includes creating analogies.

Analogies are a type of comparison between two seemingly unlike things. To create an effective analogy, the “deep structure” of the relationship between the two things being compared must be identified. “Surface details” are not important, and will likely differ. Thus,

- The deep structure of a relationship is what makes two seemingly unrelated things, related.
- Surface features are what make two seemingly unrelated things seem unrelated.

An example follows.

*A wolf is to pack in the same way that a lion is to \_\_\_\_ [pride].*

Here, the deep structure of the analogy is that the first terms (wolf and lion) are both members of a large group (pack and pride). This is the relationship that makes this analogy meaningful. A wolf *is a member of a pack*, in the same way that a lion *is a member of a pride*.

The surface features, which do not give meaning to the analogy are things like:

- A wolf is a canine, and a lion is a feline

- Lions have retractable claws, but wolves do not
- Lions hunt on the savannah, but wolves typically do not

These features do not help us make meaning from the analogy.

Your instructor wrote some analogies for your course below (Q1 – 4). Try to provide answers to these analogies. Question 5 asks you to write your own analogy question, and then try to answer it.

- 1. How is pattern formation similar in the developing embryos of plants and animals?**
- 2. As patterns develop in these embryos, well-defined axes appear that will be important in the adult organism. Can you think of something else that acts similarly?**
- 3. How are the various processes that define the different regions of a developing embryo similar to how an assembly line works?**
- 4. How is the cell-to-cell communication of developing organisms the same as communication within the nervous system?**
- 5. Now you try. Generate and attempt to answer your own analogy. A basic template to help you start follows: How is \_\_\_\_\_ [new concept] related to what you already know about \_\_\_\_\_ [experience with something similar to this concept]?**

## Activity 2

### Creating Analogies

Worksheets like this one will help you learn at a deep level so that you will be able to *use and apply* what you learn.

Remember, meaning is generated by creating two types of relationships:

1. Relationships between your own knowledge/experience and the new information  
and
2. Relationships among the parts of the new information.

### How to use analogies:

Analogies help us make these two types of connections. They are a type of comparison between two seemingly unlike things. To create an effective analogy, the “deep structure” of the relationship between the two things being compared must be identified. “Surface details” are not important, and will likely differ. Thus,

- The deep structure of a relationship is what makes two seemingly unrelated things, related.
- Surface features are what make two seemingly unrelated things seem unrelated.

An example follows.

*A wolf is to pack in the same way that a lion is to \_\_\_\_ [pride].*

Here, the deep structure of the analogy is that the first terms (wolf and lion) are both members of a large group (pack and pride). This is the relationship that makes this analogy meaningful. A wolf *is a member of* a pack, in the same way that a lion *is a member of* a pride.

### When to use analogies:

Use an analogy to help you understand relationships. So, when you read your textbook or listen to lecture, try to create analogies when you read or hear about something new. It’s also very powerful to use them while studying for exams, too. Connecting new information to your prior knowledge will make the new information much more memorable.

Your instructor wrote some analogies for your course below (Q1 – 4). Try to provide answers to these analogies. Question 5 asks you to write your own analogy question, and then try to answer it.

1. **How is gamete formation similar in plants and animals?**
  
  
  
  
  
  
  
  
  
  
2. **The first cell division in the eudicot zygote is asymmetric producing a basal cell and a terminal cell. Subsequent basal cell divisions create a thread of cells called the suspensor which anchors the embryo to parental tissue and transfers nutrients to it. Can you think of something else that acts similarly? Your example can come from concepts you've learned in other biology courses or just a general example.**
  
  
  
  
  
  
  
  
  
  
3. **How is the development of the eudicot endosperm similar to a savings account?**
  
  
  
  
  
  
  
  
  
  
4. **How is the developing embryos in humans similar to the developing embryos in plants?**
  
  
  
  
  
  
  
  
  
  
5. **Now you try. Generate and attempt to answer your own analogy. A basic template to help you start follows: How is \_\_\_\_\_ [new concept] related to what you already know about \_\_\_\_\_ [experience with something similar to this concept]?**

### Activity 3

#### Creating Analogies

By now, you know that meaning is generated by creating two types of relationships:

1. Relationships between your own knowledge/experience and the new information
- and
2. Relationships among the parts of the new information.

You also know that to create an effective analogy, the “deep structure” of the relationship between the two things being compared must be identified. “Surface details” are not important, and will likely differ.

Now, let’s be clear about **when to use** analogies.

#### When to Use Analogies [Important; READ!]

So far, most of the worksheets presented to you have provided you with example prompts to get you thinking analogically (with analogies). Take note of how the analogies have been presented to you so far.

They have been used to help compare something new to something you may already know. They have also been used to compare two new things. When listening to lecture, reading your textbook, or watching online videos, try to make deep-structure comparisons (analogies) between the new material and something you already know. You should also try to make deep-structure comparisons (analogies) between two or more component parts of the new material.

You can also use analogies to generate new insights or meaning from material you have *already* covered. Do this by creating analogies when reviewing course material for a test.

#### Practice

Your instructor wrote some analogies for your course below (Q1 – 4). Try to provide answers to these analogies. Questions 5 and 6 asks you to write your own analogy, and then try to answer it.

1. **How is circulation similar in plants and animals?**

2. **The flow of blood between the atria and the ventricles of the heart relies on differences in pressure created by changes in volume. Can you think of something else that acts similarly? Your example can come from concepts you've learned in other biology courses or just a general example.**
  
3. **How are the valves in the heart similar to kinks in a water hose?**
  
  
  
  
  
  
  
  
  
  
4. **How is diffusion of gases between the blood and body tissues similar to the diffusion of gases between the atmosphere and cells in the plant leaf?**
  
  
  
  
  
  
  
  
  
  
5. **Now you try. Generate and attempt to answer your own analogy. A basic template to help you start follows:** How is \_\_\_\_\_ [new concept] related to what you already know about \_\_\_\_\_ [experience with something similar to this concept]?
  
  
  
  
  
  
  
  
  
  
6. **Now you try. Generate and attempt to answer your own analogy. A basic template to help you start follows:** How is \_\_\_\_\_ [new concept] related to \_\_\_\_\_ [another new concept]?

## Activity 4

### Creating Analogies

This is the last analogies worksheet. Remember that analogies are used to construct meaning by identify deep-structure relationships between parts of new information, and between new information and prior knowledge.

Remember to use analogies when studying for tests, studying notes, and in lecture. Use analogies in these ways for this and other courses. Creating good analogies is difficult and takes practice, so don't give up! The fact that they are difficult is a testament to just how powerful and effective they are for learning.

If you want more practice, go back and try to think of other answers to the analogies presented in this and the first three worksheets. Or better yet, practice creating your own, and answering them. Below is some additional practice using material recently covered in class:

### Practice

Your instructor wrote some analogies for your course below (Q1 – 4). Try to provide answers to these analogies. Questions 5 and 6 asks you to write your own analogy, and then try to answer it.

- 1. How are the molecular processes similar in photosynthesis (energy acquisition) and respiration (energy use)?**
  
- 2. The movement of electrons down a transport chain in a membrane is associated with the movement of protons across that membrane. Can you think of something else that acts similarly? Your example can come from concepts you've learned in this or other biology courses or just a general example.**
  
- 3. How is the linear flow of electrons between Photosystems II and I similar to water moving past a water wheel in a mill?**





## Appendix B

Code	Description	Example
<b>0:</b> Off topic of Incomplete	This code is given to responses that make no semantic sense or are completely off topic for the course content. <i>An example “off-topic” response is given here.</i>	<i>How is the internet similar to physical sources of knowledge? They both provide information about any subject, as well as stories, help, tutorials, entertainment, and more.</i>
<b>1:</b> Simple Question or Statement	This code is given to responses that simply ask a question or make a statement. The response compares <i>X</i> to <i>Y</i> in either question or statement form, without elaboration. However, if a relationship is apparent or explicated in the response, count it as a Code 4.	<i>How is human development related to what you already know about animal development similar and different?</i>
<b>2:</b> Question or Statement +	This code is given to responses that ask a question <i>and</i> give an answer to the question, <i>but</i> the answer does not explicate a literal similarity or common relationship between base and target. In other words, <b>do not apply this code</b> if a higher code applies to the response (e.g., Analogy 1). Code 2 may still be applied if a response attempts to point out a relationship, but the explanation/elaboration is one-sided.	<i>The fertilization of the egg in plants is like a Star Wars mission with the jedi being the sperm trying to rescue the princess or find new jedi warriors.</i>
<b>3:</b> Literal Similarity	This code is given to responses that point out actual, apparent, <i>attributional</i> similarities between the base and target. <i>Attributional similarities may include features like color, shape, size, or name.</i>	<i>The concept of angiosperm, sexual reproduction and development is similar to mammalian reproduction due to the presence of male and female organs and gametes that are vital for embryo development.</i>
<b>4:</b> Analogy 1	This code is given to responses that compare base and target using one relationship <i>that highlights a similarity not based in an attribute (see code 3)</i>	<i>The SA node is similar to the coxswain in rowing as they are both responsible for keeping rhythm.</i>
<b>5:</b> Analogy 2	This code is given to responses that compare base and target using <i>more than one</i> relationship.	<i>How are the pheromones produced by fruits related to the success of modern-day Instagram celebrities? Pheromones produced by fruits attract the attention of animals that will ultimately consume them and disperse their seeds for them. Various companies (fruit) partner with modern-day Instagram celebrities (pheromones) in hopes that they will make their products look attractive to buyers (animals). The end game for these companies is to implant their products into the minds of potential buyers (various environments) in hopes that products are bought (seeds are planted).</i>