

# SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

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# SCOPE, SEQUENCE, and COORDINATION

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\*not part of the NSF-funded SS&C Project.

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## National Science Education Standard—Life Science

### Biological Evolution

Natural selection and its evolutionary consequences provide a scientific explanation for the fossil record of ancient life forms, as well as for the striking molecular similarities observed among the diverse species of living organisms.

The millions of different species of plants, animals, and microorganisms that live on Earth today are related by descent from common ancestors.

## Teacher Materials

Learning Sequence Item:

# 905

## Structures That Reveal Common Ancestry

August 1996

Adapted by: Lucy Daniel and Tom Hinojosa

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**Natural Selection and Its Evolutionary Consequences.** Students should explore homologies of animals that reveal common ancestry. They should also consider how structures without a common evolutionary origin can be similar in function but not in structure (give examples, such as the wings of birds and insects) (*A Framework for High School Science Education*, p. 108).

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4. Contents, Covers, and the Stories They Tell

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3. Alien Neighbors
4. Finger Bones

# 905

Learning Sequence

**Natural Selection and Its Evolutionary Consequences.** Students should explore homologies of animals that reveal common ancestry. They should also consider how structures without a common evolutionary origin can be similar in function but not in structure (give examples, such as the wings of birds and insects) (*A Framework for High School Science Education, p. 108*).

Science as Inquiry	Science and Technology	Science in Personal and Social Perspectives	History and Nature of Science
<p>Fly Away <b>Activity 1</b></p> <p>Ideas of Icarus <b>Activity 2</b></p> <p>Swim for It! <b>Activity 3</b></p> <p>Contents, Covers, and the Stories They Tell <b>Activity 4</b></p> <p>Analogous Structures: Wings <b>Assessment 1</b></p> <p>Aliens Alike? <b>Assessment 2</b></p> <p>Alien Neighbors <b>Assessment 3</b></p> <p>Finger Bones <b>Assessment 4</b></p>			<p>Analogous Structures—Wings <b>Assessment 1</b></p> <p>Aliens Alike? <b>Assessment 2</b></p> <p>Alien Neighbors <b>Assessment 3</b></p>

## Suggested Sequence of Events

### Event #1

#### Lab Activity

1. Fly Away (40 minutes)

### Event #2

#### Lab Activity

2. Ideas of Icarus (20 minutes)

#### Alternate or additional activity

3. Swim for It! (15–20 minutes)

### Event #3

#### Lab Activity

4. Contents, Covers, and the Stories They Tell (35–40 minutes)

### Event #4

#### Readings from Science as Inquiry, Science and Technology, Science in Personal and Social Perspectives, and History and Nature of Science

#### Suggested readings:

Alexander, R.M., "How Dinosaurs Ran." *Scientific American*, April 1991, pp. 4–10.

Gould, S.J., "Common Pathways of Illumination." *Natural History*, December 1994, pp. 10–20.

Meadows, R., "Fossil Molecules." *Chem Matters*, Vol. 6, No. 2, 1988, pp. 4–7.

*Assessment items are at the back of this volume.*

## **Assessment Recommendations**

This teacher materials packet contains a few items suggested for classroom assessment. Often, three types of items are included. Some have been tested and reviewed, but not all.

1. Multiple-choice questions accompanied by short essays, called justification, that allow teachers to find out if students really understand their selections on the multiple choice.
2. Open-ended questions asking for essay responses.
3. Suggestions for performance tasks, usually including laboratory work, questions to be answered, data to be graphed and processed, and inferences to be made. Some tasks include proposals for student design of such tasks. These may sometimes closely resemble a good laboratory task, since the best types of laboratories are assessing student skills and performance at all times. Special assessment tasks will not be needed if measures such as questions, tabulations, graphs, calculations, etc., are incorporated into regular lab activities.

Teachers are encouraged to make changes in these items to suit their own classroom situations and to develop further items of their own, hopefully finding inspiration in the models we have provided. We hope you may consider adding your best items to our pool. We also will be very pleased to hear of proposed revisions to our items when you think they are needed.

## Science as Inquiry/Science and Technology

**Fly Away****Is there ever just one way to solve a problem?****Overview:**

This activity is intended to introduce the concept of analogous structures, parts similar to one another in function but not structure, as in the wing of a bird vs. the wing of a bat. By experimenting with variety and originality now, students will have an easier time understanding natural examples in the next two activities.

*Safety considerations:* Students should be reminded of the danger of throwing objects at one another. Paper cuts are also common during this activity.

**Materials:****Per student:**

paper, 2 or 3 sheets of varying size  
 paper clips, 1 or 2  
 scissors  
 glue stick

**Procedures:**

Students should work in teams of two. Fresh sheets of paper are not necessary; you may wish to use previously used paper such as old handouts. Availability of different sizes or weights of paper will encourage variety. Students design and construct paper airplane gliders of various shapes that will stay in the air for at least five seconds (you may adjust the time if this seems too long), and that will travel a certain linear distance from the starting launch point (you should determine an appropriate distance). The challenge is to create designs that are as different as possible but that meet the criteria. Wild ideas should be encouraged. Students will likely create different models, and no two gliders may be the same.

Students should examine and/or test all the models made in class. They should list and describe all the characteristics that the gliders have in common. Similarly, they should list and describe all the characteristics that are different. A data table should be constructed and used to organize their notes (see sample below).

Name of glider or creator	Unique things about this glider	Things this glider has in common with all others

**Background:**

The idea is to guide students to make the connection to the biological concept of analogous structures and potential for adaptation. An explanation of the physics of flight is not important at this time. It is better to let students experiment with various shapes, sizes, and designs.

It is best to carry out the flight trials indoors to provide a standardized test environment. You may wish to hang particularly creative examples from the ceiling for future discussion.

*Post lab discussion:* Bring out the idea that though the various paper planes were of different shapes (some big and sleek; other with big wings, etc.) they managed to do the same job (staying in air for some time).

This task should be ideal for assessing such abilities as:

1. proposing a design hypothesis
2. retesting ideas based on creating a standardized test environment
3. data collection
4. making analogies

**Variations:**

If students are too skilled, then the criteria can be strengthened (more time, distance). However, it is claimed that the world record is only 18.7 seconds.

Adapted from: none

## Science as Inquiry

**Ideas of Icarus****Are all wings alike? Are all winged creatures related?****Overview:**

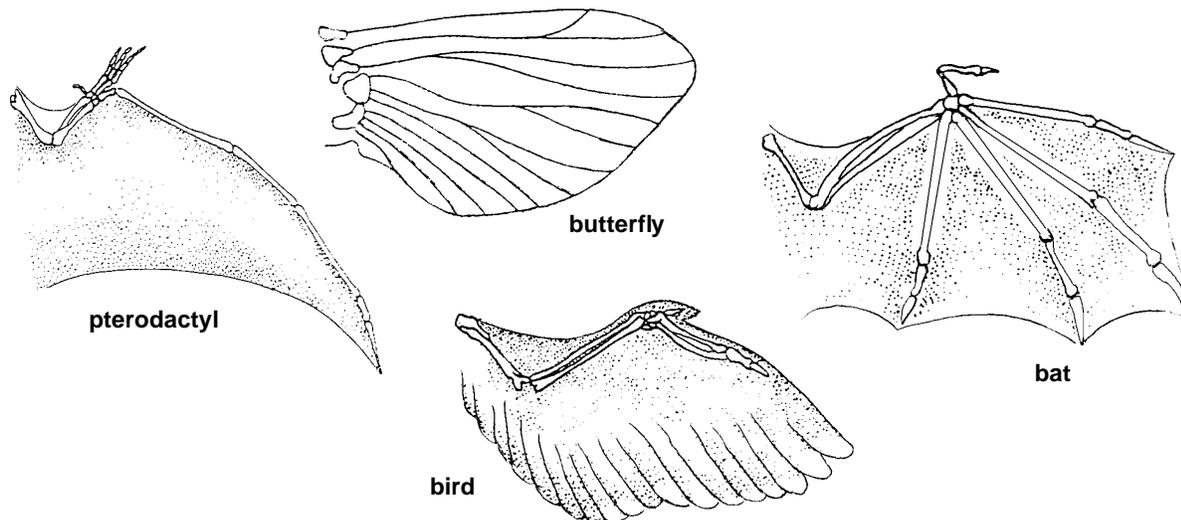
This activity asks students to compare analogous structures, i.e., body parts similar to another in function but not similar in structure. It is intended to show how different organisms are affected by similar environmental conditions.

**Materials:****Per student:**

illustrations of wings (included with Student Materials)

**Procedure:**

Students work in small groups or alone. They study the structures of the pterodactyl wing, butterfly wing, bat wing, and bird wing shown below, noting the similarities and differences among them. Have them construct a data table to organize their answers and observations.



Possible student responses:

***Similarities***

same shape of wings  
all used for flying  
each creature has at least two wings

***Differences***

different shapes of bones  
butterfly has no bones  
wings vary in size

Students are asked questions that include the following concepts and ideas: The bat is a mammal, the butterfly is an insect, and the bird is a bird; the pterodactyl may be classified as a reptile. As such, none of these organisms are closely related. Each of these creatures has developed structures for flying (wings). These unrelated organisms live in similar environments. The wing is an adaptive response related to the need for flying.

**Background:**

Bird, bat, and butterfly wings are not similar in structure but they do have the same function. The wings of all three evolved independently in three distantly related groups of ancestors. Any body structure that is similar in function but different in structure is an *analogous* structure. Analogous structures cannot be used to show evolutionary relationships among organisms, but they do provide evidence of evolution. The different ancestors of birds, bats, and butterflies independently adapted to similar ways of life in similar environmental conditions. Analogous structures are often completely different in internal anatomy, since these parts are not derived from common ancestral structures.

The process by which distantly related organisms develop similar characteristics is called *convergent evolution*. This pattern of evolution occurs when different species are subject to the same or very similar environments and thereby experience the same selection pressures. This process is in contrast to *divergent evolution*, the process by which related organisms become less similar over time and sometimes results in the formation of a new species. The occurrence of dorsal fins and streamlined shapes in fish and whales are examples of convergent evolution. The variation in the shape and size of beaks of (Darwin's) finches is an example of divergent evolution.

**Further Variations:**

Show students pictures of a seal and a penguin. Ask them to compare the two. Other examples of convergent evolution include analogous resemblances between certain Australian marsupials and placental look-alikes that have evolved independently on other continents. (There are marsupial wolves, mice, and moles.) Convergent evolution occurs when organisms are subjected to similar selective pressures.

Adapted from:

Goodman, H.D., L. Graham, T. Emmel, and Y. Shechter, *Biology Today*. Orlando, FL: Holt, Rinehart and Winston, Inc., 1991.

alternative/extension activity for Event 2

*Teacher Sheet*

## Science as Inquiry

### Swim for It!

#### What makes a good swimmer? Are fish and aquatic mammals related?

#### Overview:

This activity can be done either in addition to Activity 2 or as an alternative. It provides another experience with analogous structures exhibited by unrelated creatures who share a common environment. Observations of body parts with similar function but whose structures do not share a common evolutionary origin should lead to an understanding that natural selection causes convergent evolution.

#### Materials:

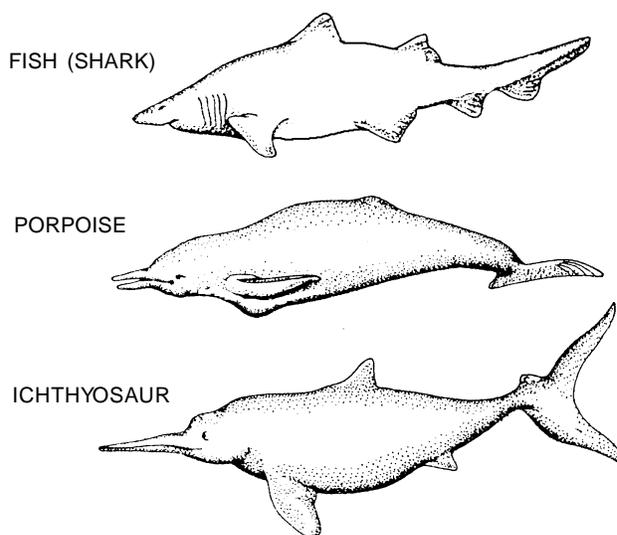
##### Per student:

illustrations of fish, porpoise, and ichthyosaur (included with Student Materials)

#### Procedures:

Students compare the body shapes of the fish and porpoise and then compare their body shapes with the fossil aquatic ichthyosaur (reptile).

Students should analyze their observations of the three animals and recognize the following concepts or ideas: all of these animals live(d) in water; all their shapes can be described as streamlined, which would be an adaptation for rapid swimming in water; these animals are not closely related in that they represent three different classes of animals (fish, mammal, reptile); some obvious differences between them are the presence of gills in the shark (fish characteristic) and the presence of lungs in the porpoise, requiring it to come to the surface for oxygen; these unrelated organisms live in similar environments and, therefore, show similar physical adaptations (i.e., streamlined shape) to help them move efficiently through the water.



#### Background:

The structural design of the porpoise, fish, and ichthyosaur (an extinct aquatic reptile) is an example of convergent evolution. Convergent evolution is the pattern of evolution in which distantly related organisms evolve similar traits. Convergent evolution occurs when unrelated organisms

occupy similar environments and face similar selection pressures. The streamlined shape of fish, porpoises, and the extinct reptile is an adaptive response related to the need for moving efficiently through the water.

**Variations:**

Many variations are possible using different species, all of which exhibit a similar (analogous) structure designed to meet the pressures of a given environment. You may wish to assign this task of identifying other examples as an extension of this activity or as homework.

Adapted from: none

## Science as Inquiry

**Contents, Covers, and the Stories They Tell****What do the bones of animals reveal about their ancestry?****Overview:**

Students examine the bone structures of several different mammals in order to explore homologies that reveal common ancestry.

**Materials:****Per lab group:**

illustrations of bones of mammal limbs (included with Student Materials)

illustrations of fur/skin-covered mammal limbs (included with Student Materials)

**Procedures:**

Students should work alone or in pairs. There are two student lab sheets for this activity labeled Lab Sheet 1 and Lab Sheet 2. It is intended that students will not be given Lab Sheet 2 until they have completed Part 1 of the activity.

In Part 1, students are asked to examine the bones of forelimbs from seven different mammals labeled A–E. They must identify each bone set based on their observations and knowledge of the seven mammals. You may choose whether or not to tell students beforehand the seven possible choices for the identities of the bones. If students have sufficient background, you may wish to let them speculate based entirely on their prior knowledge. The bone sets are correctly identified as A. bat; B. mole; C. opossum; D. human; E. wolf; F. sea lion; G. elephant.

Students should complete a data table with their choices and key characteristics of the bones that led to their decisions. You should remind them that the bones are not drawn to scale.

In part 2, students examine the skin- and/or fur-covered illustrations of limbs from the same seven mammals and describe the relationship between each limb structure and its normal function. They should speculate on why the bone structures show similarities while the animals themselves exhibit widely different behaviors.

**Background:**

Comparative anatomy of homologous structures, such as the forelimbs of the seven mammals in this activity, can provide early clues that these animals share a common ancestor and that evolutionary processes (natural selection) have created the observed variations on a common design (derived with modification from a characteristic in a common ancestor). Despite the obvious differences in shape and size, all mammalian forelimbs are composed of similar bones arranged in a comparable pattern. Along with ancestral implications, these homologous structures illustrate the phenomenon known as adaptive radiation. This term describes the process whereby mammals are able to radiate into a vast range of habitats by adapting physiologically and anatomically to environments as different as forest, plains, water, and underground.

Very often the embryological development of a feature provides better evidence of homology than its final form. A comparison of developmental stages among vertebrates led Ernst Haeckel (1834–1919) to propose his famous principle “ontogeny recapitulates phylogeny.” This principle claims that the development of an individual (ontogeny) reflects the stages through which the individual’s species has passed during its evolution (phylogeny). Today, it is clear that this idea is an oversimplification and can be misleading. While it is true that early developmental sequences of all vertebrates show amazing similarities, there are important deviations from the general developmental plan seen between different species. However, analyzing the development of particular features (such as forelimbs) can be instructive.

**Variations:**

If available, skeleton models or separate bones from various mammals should be used along with the illustrations provided in this activity. Students could be asked to name and label the bones for each of the seven mammals. A human reference should be provided. The corresponding bones for each animal could be colored the same to highlight the similarity in bone pattern. The bones labeled should include: scapula, humerus, radius, ulna, carpals (wrist), metacarpals (hand), and phalanges (fingers).

Adapted from:

Futuyma, D. J., *Evolutionary Biology*, 2nd Edition, Sunderland, Mass.: Sinauer Associates, 1986.

Illustrations by Lisa Carisio, NSTA SS&C California Coordination Center, Santa Clara, CA, 1996.

Science as Inquiry/  
History and Nature of Science

### **Analogous Structures: Wings**

**Item:**

Birds, flying insects, and bats evolved from very different ancestors. Yet all of these animals have wings. How can such different structures have very similar functions? Choose three unrelated flying animals and prepare a chart to show the similarities and differences in their wings and the way they fly.

**Answer:**

Students should construct a chart or table to house their answers. While answers may vary depending on the organisms chosen, possible sample answers are given below. Students should be encouraged to choose organisms not included in the actual lab activities.

<i>Flying animals: hawk, flying squirrel, dragonfly</i>	
<b>Similarities</b>	<b>Differences</b>
all can fly	different sizes of wings
same basic wing shape	some have bones in wings; others don't
each creature has at least two wings	some glide; others beat wings to fly

Although each organism has a different type of wing and flies differently, each one is better able to survive since they can fly. Even though they come from different ancestors, the fact that these organisms live in the same basic environment (air) means that they all derive an advantage by flying.

Science as Inquiry/  
History and Nature of Science

**Aliens Alike?**

**Item:**

A team of scientists lands on an unexplored planet. It finds two different organisms thriving there. One is a vertebrate and the other is a nonvertebrate. Your task is to help the scientists determine the degree to which the two animals are related.

In comparing animals, scientists often make note of *analogous structures*, structures that have the same function but not the same biological structure (like the wings of birds compared to the wings of insects); and *homologous structures*, structures that have the same underlying biological structure although they may perform different functions (like the arm of a human and the flipper of a seal).

Explain how you might use the concepts of analogous and homologous structures to help determine how biologically similar the two types of organisms are.

**Answer:**

The teacher might select two specific organisms that are somewhat similar so that students can focus on these examples.

Science as Inquiry/  
History and Nature of Science

**Alien Neighbors**

**Item:**

A team of scientists lands on an unexplored planet. It finds two different organisms living there—one is a vertebrate and the other is a nonvertebrate. Your task is to help the scientists find evidence that the two animals are *not* related even though they live in the same environment.

Describe what traits or characteristics would be most likely to provide evidence of unrelatedness.

**Answer:**

The teacher might select two specific organisms that are somewhat similar so that students can focus on specific traits in these examples. Students may cite structural and/or behavioral differences, or may discuss the use of DNA analysis to distinguish between the two organisms. Some students may suggest determining a detailed genealogy for both organisms.

## Science as Inquiry

**Finger Bones****Item:**

Humans, whales, and birds all have finger bones. Which of the following best describes an appropriate reason for this finding?

- A. All of these animals have fingers.
- B. Since humans have finger bones, all other creatures beneath us must have finger bones.
- C. All of these creatures have a common ancestor; finger bones have remained and developed different usages due to selective pressures.
- D. This is a misnomer by scientists; these bones shouldn't be classified as finger bones at all.

**Justification:**

How does the environment affect different aspects of a species through time?

**Answer:**

C. Differing environmental conditions placed different selective pressures on the phenotypic expression of the gene for finger bones, leading to changes in their function over time.

<b>Item</b>	<b>Consumables</b>	
	<b>Quantity per student</b>	<b>Activity</b>
paper, of varying sizes	2 or 3 sheets	1
glue stick	1	1
illustrations of wings (included with Student Materials)	—	2
illustrations of fish, porpoise, and ichthyosaur (included with Student Materials)	—	3
illustrations of mammal bones (included with Student Materials)	—	4
illustrations of mammal limbs (included with Student Materials)	—	4

<b>Item</b>	<b>Nonconsumables</b>	
	<b>Quantity per lab group</b>	<b>Activity</b>
paper clips	1 or 2	1
scissors	1	1

**Key to activities:**

1. Fly Away
2. Ideas of Icarus
3. Swim for It!
4. Contents, Covers, and the Stories They Tell

**Activity Sources**

Futuyma, D.J., *Evolutionary Biology*, 2nd Edition. Sunderland, Mass.: Sinauer Associates, 1986.  
 Goodman, H.D., L. Graham, T. Emmel, and Y. Schechter, *Biology Today*. Orlando, Fla.: Holt, Rinehart, and Winston, Inc., 1991.