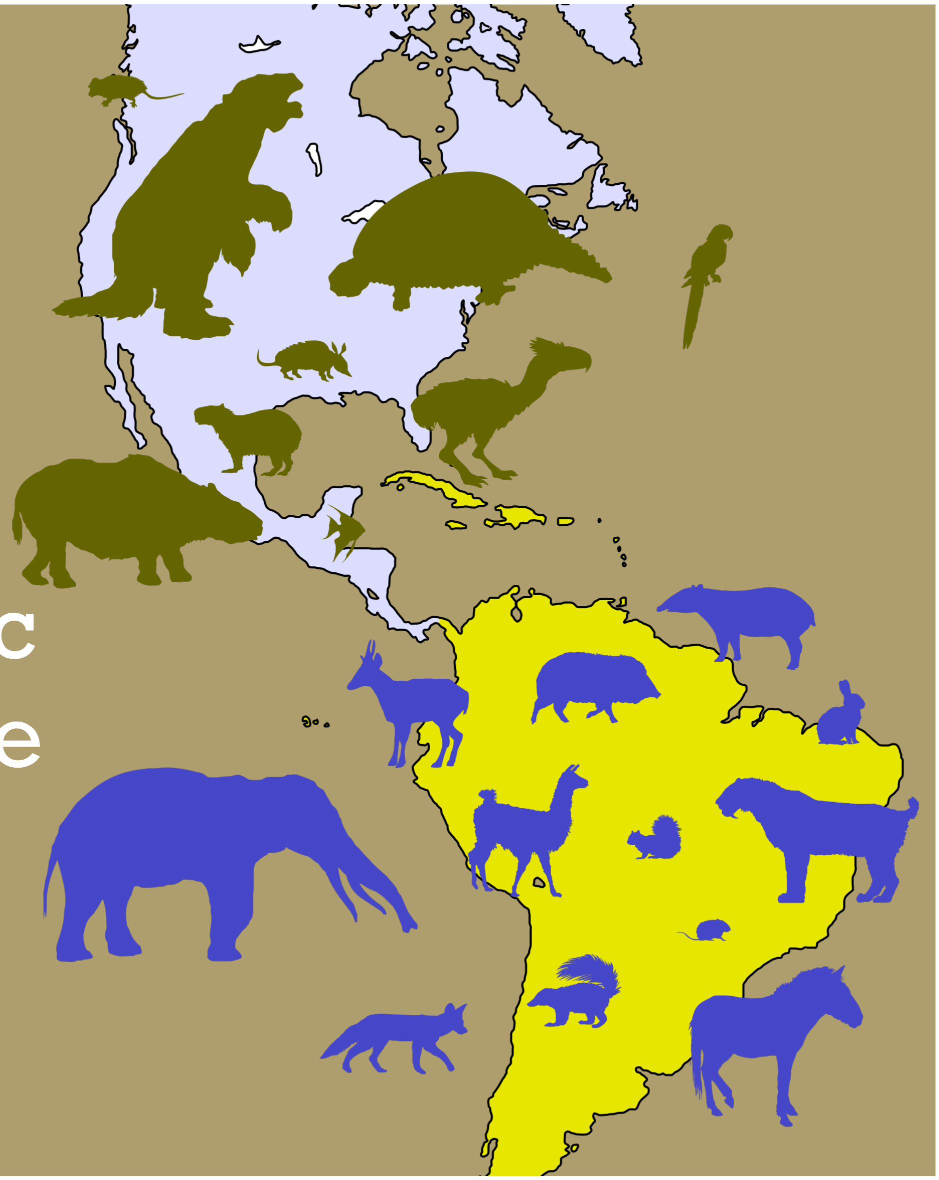

Great Biotic Interchange

Lesson Plan for Sixth Grade Students

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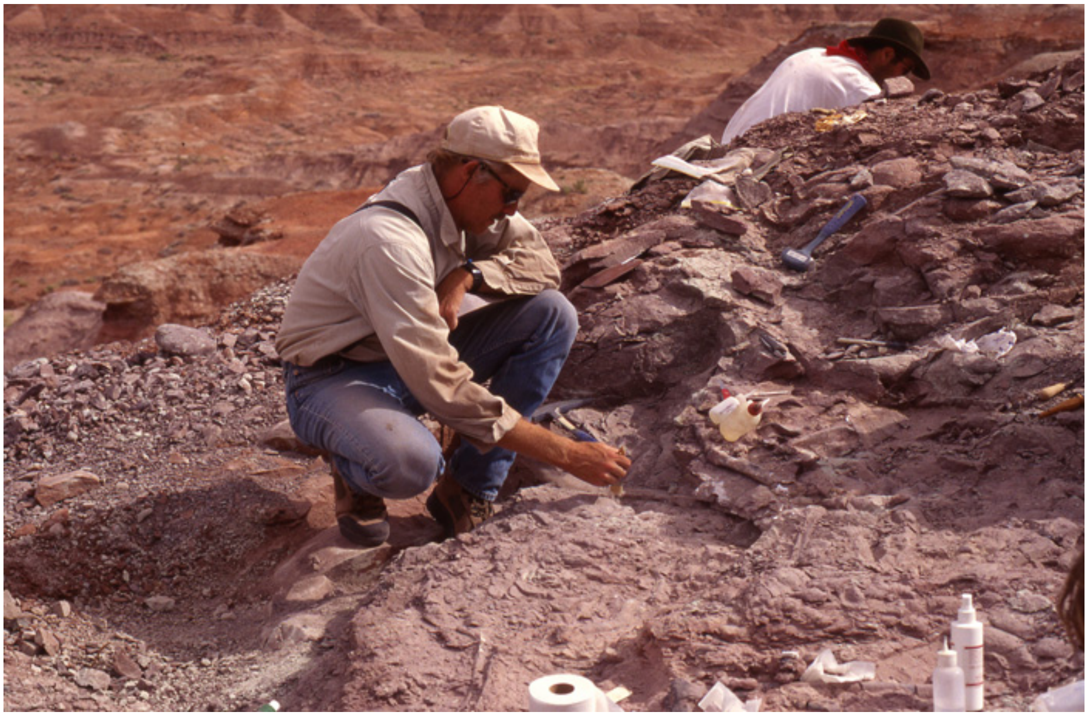

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The environment and the organisms that dwell in it are inherently connected. The state of the environment is in a constant state of flux, prompting changes in organisms to facilitate their survival. This special, evolutionary relationship between organisms and their habitat is one of the unifying concepts of biology, yet in the United States, there is a widespread misunderstanding of – and in some cases disbelief in– evolution. It is important that students begin at a young age to grasp the theory of evolution and understand interdependent relationships in ecosystems. The Great Biotic Interchange is one of the best-documented examples of how alterations in the environment due to geological forces cause biological changes in organisms and ecosystems (Vermeij 1991). This event clearly illustrates how changes in the environment can trigger evolutionary changes and alter biomes and ecosystems. In this way, the Great Biotic Interchange is an excellent topic for fostering sixth grade students' understanding of "interactions among organisms across multiple ecosystems," as set forth by Next Generation Science Standards (NGSS). It incorporates two of the standards: analyzing and interpreting data from fossils to provide evidence of ancient organisms and their environments, and constructing an argument that in particular environments, some organisms survive well while others do not.

The main objectives of this lesson are to:
1. Increase awareness of the importance of fossils in understanding Earth's history.
2. Learn about Earth's geological processes and how they impact multiple ecosystems.
3. Develop understanding of the Great Biotic Interchange and how it shaped ecosystems today.

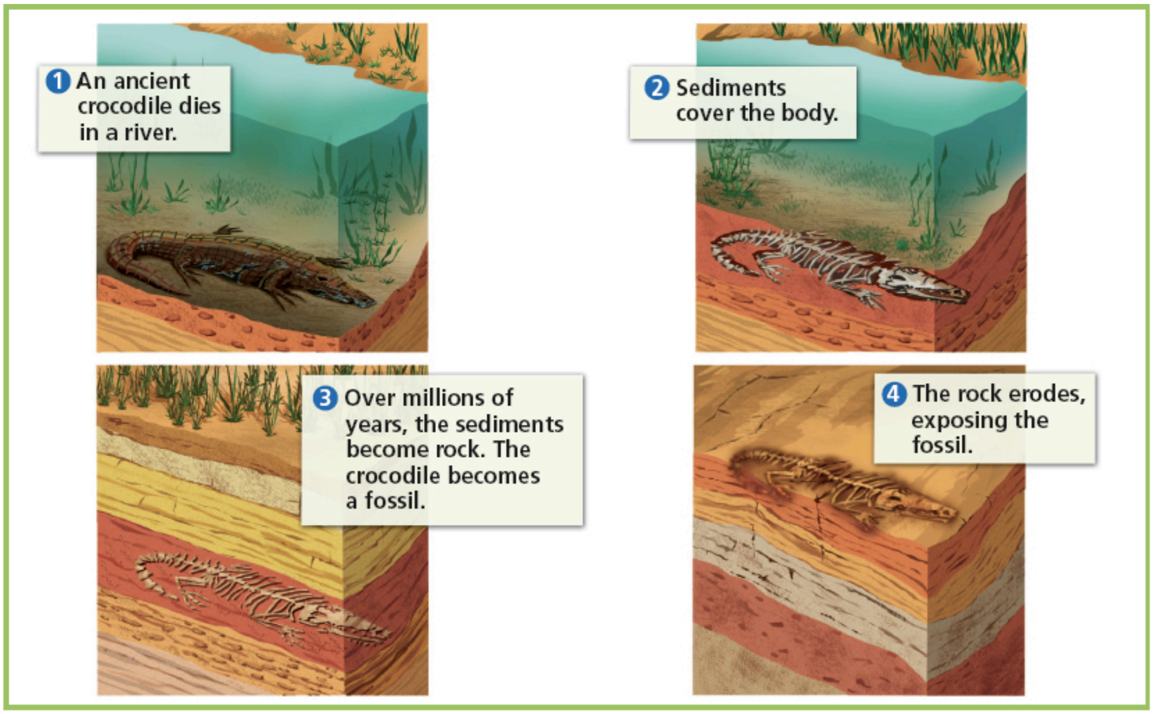


Fig. 1

Fossil Formation (Pearson Education, Inc.)

Activity 1: Learning about Earth's History with Fossils

Why are paleontologists interested in studying fossils? What do fossils tell us about the environments of and animals that lived in North and South America?

Begin with passing around fossils (real or fake) and asking students how old they think the fossils are. Explain how the class must begin to think in very large units of time than what they are normally accustomed to. Instead of thinking about time in days, months, or years, the Earth's history is documented in layers of rocks deposited over 4.6 billion years. A graphic representation of fossil formation is helpful for students to visualize the process of fossil formation (Fig. 1). Share with students how paleontologists (those who study fossils) find fragments of animals that were alive thousands to hundreds of millions of years old. By analyzing these animal fragments, scientists can gain an understanding of how these animals lived and interacted with their environments. Fossils found in North and South America that date to 2-3 million years ago reveal that the animals on each of these continents were once separated and very different from each other.

Hand out a sheet with a blank map of North and South America, with the continents disconnected from one another (Fig. 2), and grey animal cutouts big enough for students to write on, with half labeled North America and the other half South America (Fig. 3). The students will take notes on the qualities of each of the continents and notes on the animals' characteristics during the following discussion.

With supporting illustrations, explain how North America has been connected to Asia and Europe by land bridges multiple times over the

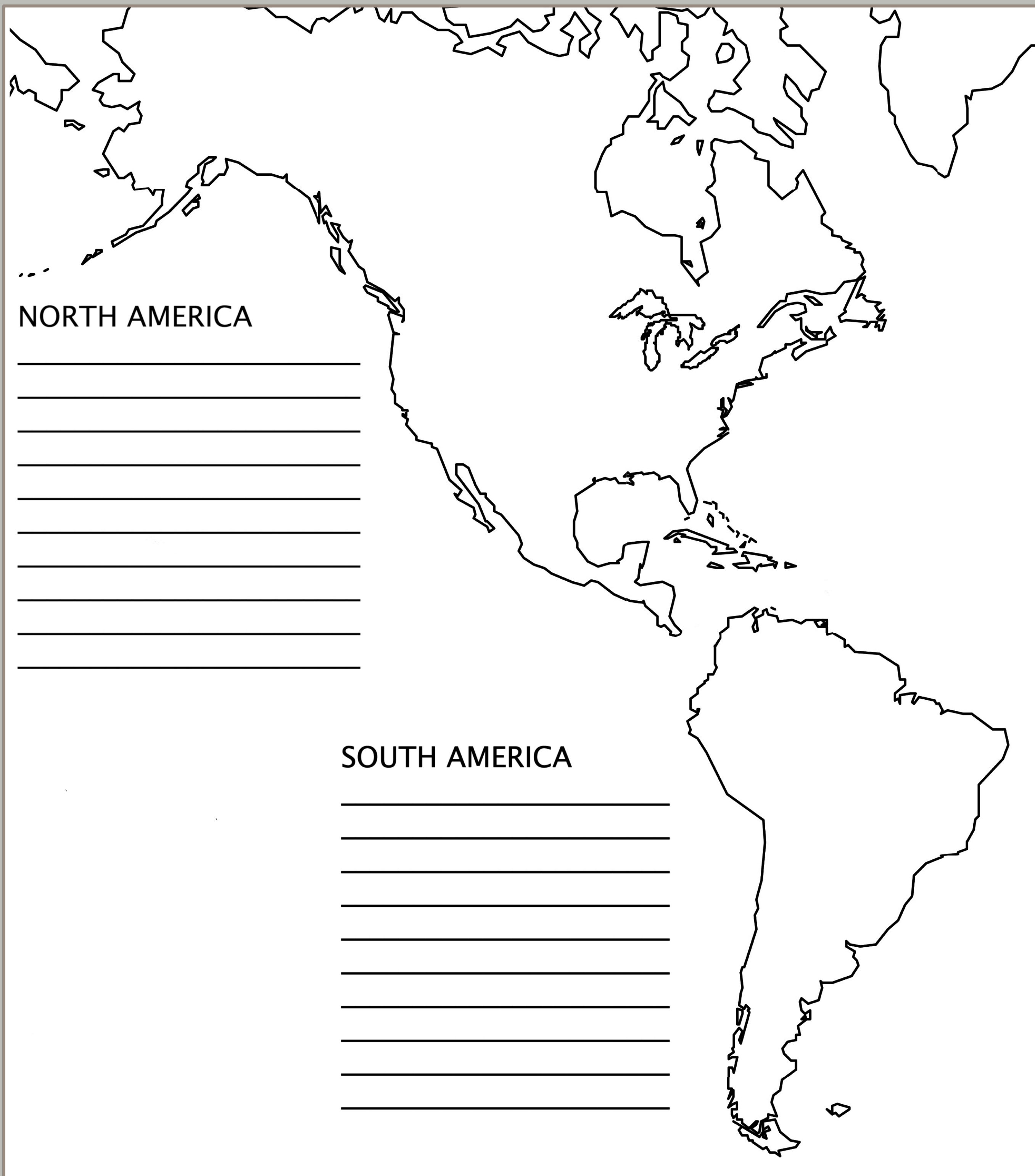


Fig. 2
Handout

Fig. 3
Activity 1 Animals

course of millions of years. The students should draw arrows on the upper left and right areas of North America on their maps to indicate connections with Asia and Europe. Show the students images of animals that evolved in North America, and ask them to discuss in groups why they think animals in North America, Asia, and Europe were quite similar. Each group will share with the class their best explanation. While crediting the efforts of all groups, explain how the connections with Europe and Asia influenced the animals in North America. Having learned about natural selection in years prior, the students will have a basic understanding of natural selection. It is not necessary to go in depth about the scientific evidence behind the evolution of animals in North America, but it is important to emphasize how animals on this continent were the product of "survival of the fittest." As Asian and European species invaded North America, they competed for food and living space, leaving the remaining, most fit species from these three continents best adapted to living in North America (Marshall 1998). Students will have filled out the following about North America: connections to Europe and Asia and animals are similar to connecting continents and also strong.

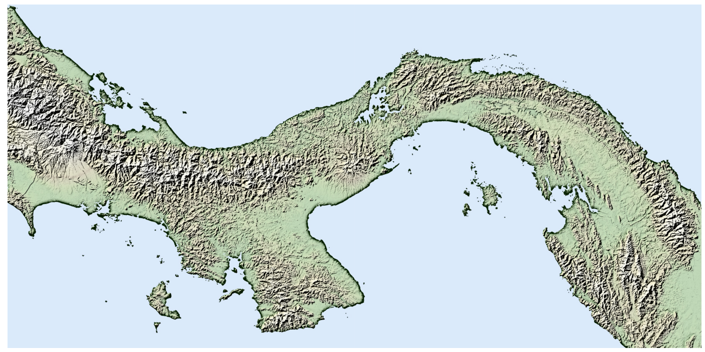
Next, show the students images of animals that live in Australia. Most of the species on this continent cannot be found anywhere else; for example, koala bears and kangaroos are particular to this region. Have students to reflect on the differences in continent land connections: in North America, which is connected to other continents, the animals look similar, but in Australia, which is essentially an island continent, animals look strikingly different from those living anywhere else. Ask the students to discuss in groups if they think that South America on their map will have animals similar to North America or Australia. By noticing that South America was a huge island continent, most will come to the conclusion that the species in South America evolved in a world of their own and thus looked much different (Marshall 1998). Show the students images of animals special to South America, such as *Titanis,* the monstrous bird that once roamed the island continent (Fig. 4).

Have the students compare their maps and animals of North and South America. Whereas the animals in North America are strong because of their connections to Europe and Asia, explain to the students that the isolated environment of South America left their species less adapted for competing with outside predators.

Fig. 4
Titanis

Activity 2: The Formation of the Isthmus of Panama

How did the rising of the Isthmus of Panama impact the ecosystems of North and South America?



Instead of explaining the process of the formation of the Panamanian land bridge through pictures, students will be far more engaged with the topic by watching an interesting video made by the National Geographic, titled *The Clash of the Americas*. From 7:20 to 9:46, this video, narrated in language that can be understood by this age group, demonstrates in a clear and legible manner how plate tectonics in the Earth's crust shift to create new land formations. The video clip explains how the Isthmus of Panama formed 2.5 million years ago, after 65 million years of plates shifting to create this land bridge. While watching the film, the students will fill out a handout to reinforce and remind students what they learned during the movie and also draw on their map from the previous activity a connection between the two continents.

After the clip is finished, point out how the formation of the Isthmus of Panama created a closed gate between the previously connected Pacific and Atlantic Oceans. It is interesting to note that even before the seaway closed, some species started experiencing separation because the land around where the isthmus would form was becoming increasingly shallow; some animals were not able to tolerate these conditions (Woodburne 2010). Thus, barriers need not be fully formed in order to effectively separate population genetically (Vermeij 1993). After the separation, mollusks and large suspension feeding animals, such as whales, experienced diversification (Vermeji 1993).

Share with the students that the creation of the Isthmus of Panama due to plate tectonics allowed for the flow of land mammals between North and South America (Webb 2006). Emphasize how such dramatic physical changes triggered what is known as the Great Biotic Interchange: when major new biological interactions between the two previously separate American continental biotas took place (Webb 2006). The pattern of biotic interchange is strongly influenced by the adaptational attributes of species involved (Vermeij 1991); with this information, along with the information learned in Activity 1, have the students discuss in groups possible scenarios of interactions among the organisms from the North American and South American ecosystems. Each student will write in their science journals their predictions with supporting evidence from their maps and animals. Review students' proposed solutions, and begin to guide their thinking towards the outcomes supported by scientific research (Activity 3).

Link: https://www.youtube.com/watch?v=Lrj8AWz-OUA

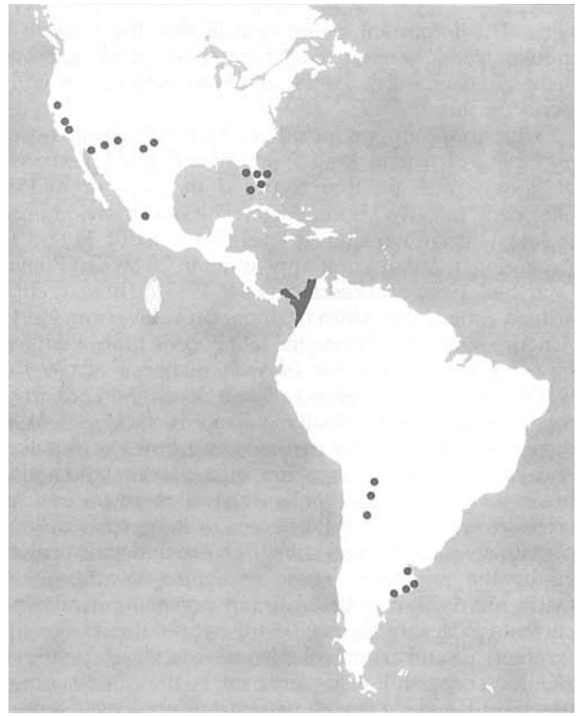


Fig. 5

Panamanian Land Bridge and Sites of Interchange Fossils

(Marshall 1998)

Activity 3: The Great Biotic Interchange

What species were introduced to North and South America during the Great Biotic Interchange?

We know that the Great Biotic Interchange took place because paleontologists have discovered fossils in various sites in North and South America (Fig. 5). Write on the board the two factors that dictated the interactions between North and South American animals: adaptational attributes of the animals and climate conditions. Having already reviewed adaptational attributes of species in North and South America prior to the Great Biotic interchange, explain to the students that climate conditions also played a large role in determining the dispersal of animals after the land bridge formed (Webb 1991).

Hand out two maps of North and South America, connected by the Panama Land Bridge (Fig. 6), with one map labeled Phase 1 and the other map labeled Phase 2. The maps will be used to illustrate how the migration patterns of animals was linked to climate conditions. The students should write down descriptions of the environment during each phase in the space provided.

When the continents first collided, it was hot, humid, and most of Central America and a significant middle portion of South America were covered in rainforest (Webb 1996). Savanna habitats, meanwhile, contracted into disjunct areas (Marhsall 1988) (Fig. 7A). Show the students an image of the distribution of landscapes (Fig. 8A), and on their Phase 1 map, the class will color in the rain forest and savanna areas in different colors. After the first humid phase, the second phase began when glaciers in the Northern Hemisphere developed, causing global temperatures to drop (Woodburne 2010). Cooler temperatures meant a drier, more arid climate, resulting in a decline in rainforests. The savannas were united by a corridor that created a north-south route that stretched from South America to the southern United States and east to Florida (Marshall 1988) (Fig. 7B). Students will draw this different landscape (Fig. 8B) on their Phase 2 map, again coloring rain forest and savanna areas in different colors.

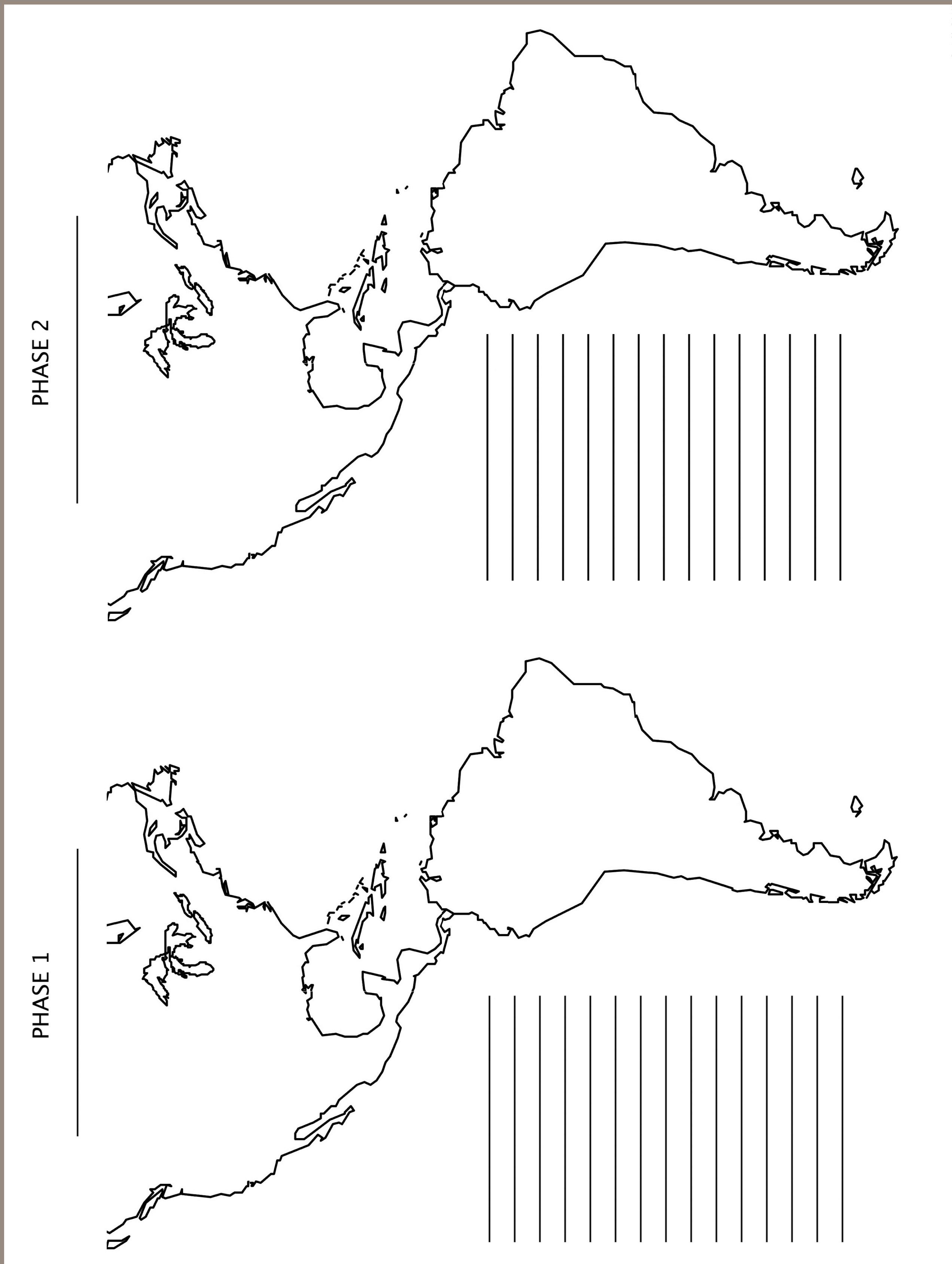


Fig. 6

Handout

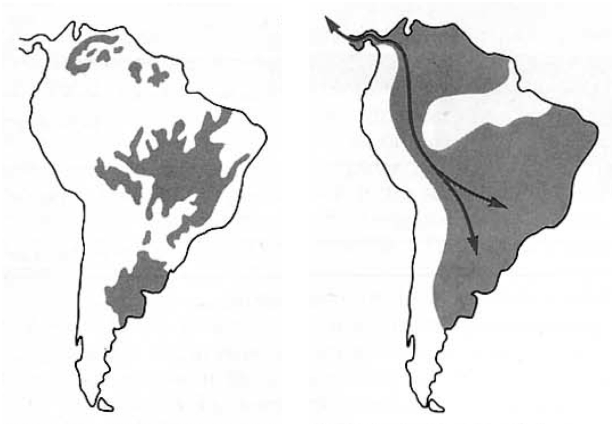
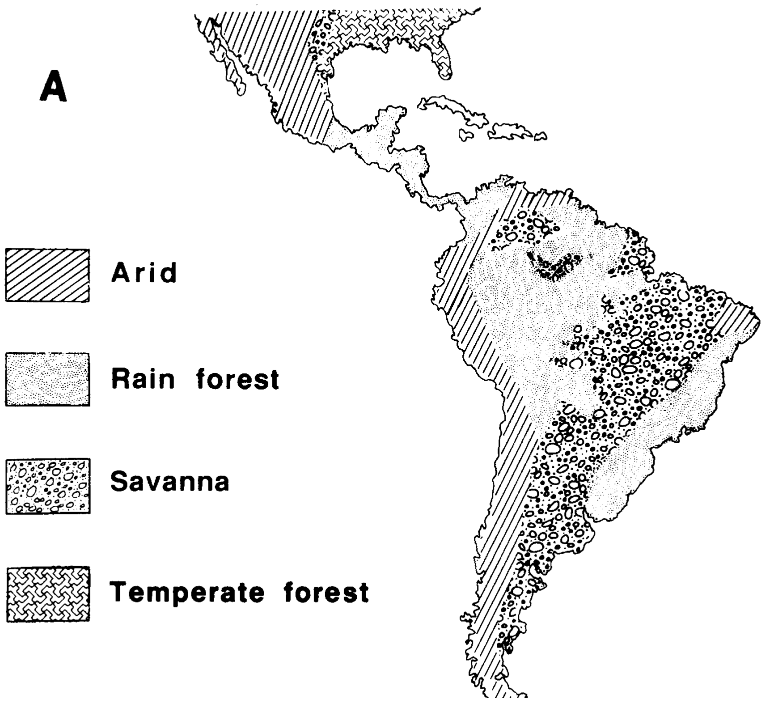


Fig. 7

A. Savanna habitats contracted into disjunct areas

B. Savanna habitats united by corridor along eastern side of the Andes

(Marshall 1998)



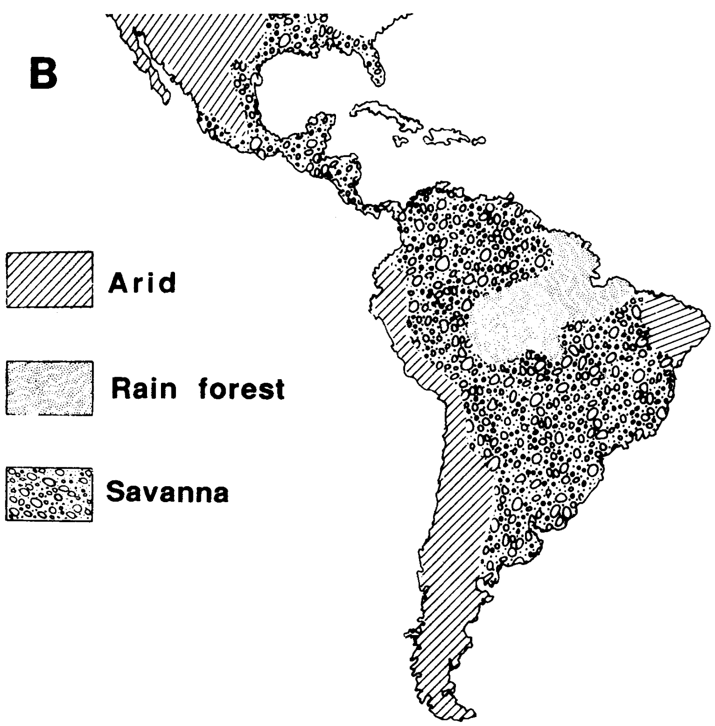


Fig. 8

Approximate distribution of four major landscapes in the American tropics during two phases of the Late Cenozaoic

A. Phase 1 dominated by rainforest

B. Phase 2 dominated by savanna

(Webb 1991)

` Show the class images of animals that lived in South America, such as *Didephis* (marsupial), *Nothrotheriops* (ground sloth), and *Pampatherium* (relative of the armadillo) (Woodburne 2010). These animals were well suited for living in tropical, humid environments (Webb 2006). Species in North America, on the other hand, were better suited for savanna-like habitats because of North America's larger amount of temperate landscapes (Webb 1996). Students will record this information on their animal cut outs from the first activity.

It is important to note that interchange is often highly one-sided, with movement in one direction across a former barrier predominating over that in the other direction (Vermeij 1991). Armed with this information, students will be able to journal responses to the following questions:

1) During the first phase, when the climate was humid and dominated by rain forests, which were more successful at migrating: North American or South American animals?

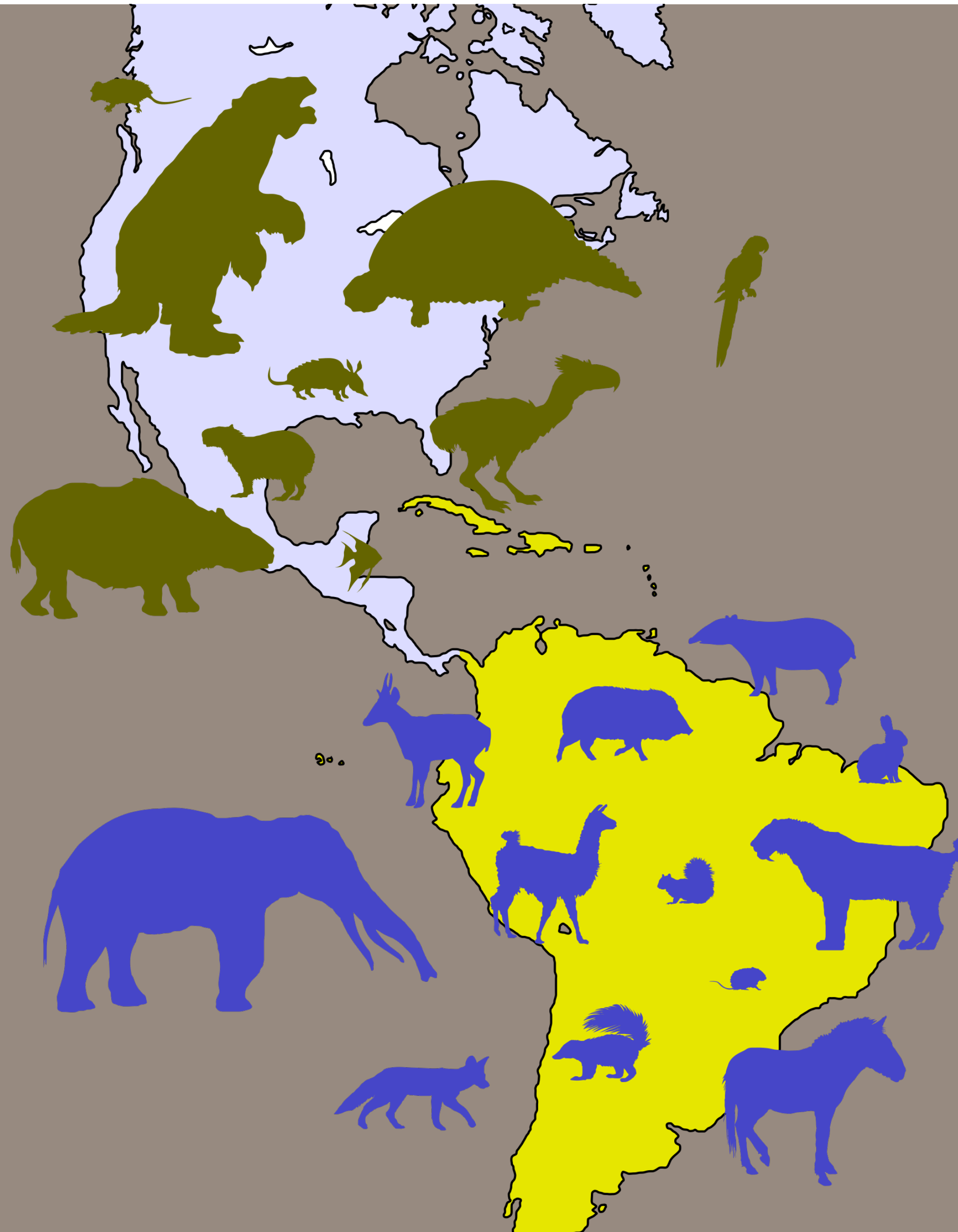
2) During the second phase, when the climate was arid and dominated by savannas, which were more successful at migrating: North American or South American animals?

Give the students enough time to think critically and review the information from all three activities so they can produce a thoughtful response. Assemble the class into groups of three, with each student sharing their answers and justifications. This will give the students the opportunity to collaborate, to see different ways of thinking, and to revise their answers.

Reconvene class discussion. Because South and Central America were covered by rainforests during the first phase, South American species were the more successful migrants. These animals were well adapted to the tropical, humid environment, thereby enabling their survival (Webb 2006). Upon arrival in North America, South American species did not compete to replace North American species (Webb 1996). The most interesting of these early dispersants was the Titanis ground bird discussed earlier. Titanis, which stood at a height of over 3 meters, was the only large terrestrial carnivore in South America when the land bridge appeared, and it was the only large South American carnivore to disperse to North America, where it is recorded in fossils found in Florida (Marshall 1998). Birds followed the same path as Titanis, with most migrating from South to North America (Weir et al. 2009).

During the second, arid phase, the broad, open country pathway from North to South America allowed for North American species to move south, as these animals were well adapted to the savanna environment (Woodburne 2010). North American species that moved south were most successful in temperate grasslands, cold winter deserts, and mountain systems in South America (Webb 2006). North American invaders were able to penetrate deeper into South America than South American species did in the north, and once they arrived in their new habitat, North American species replaced South American marsupials and ungulates, among other mammals (Vermeij, 1991). The evolution of North American animals to be competitive and defensive accounts for the asymmetrical interchange (Vermeij 1991).

Ask the students to think about if they believe North American species made a large difference in the ecosystem makeup of species in South America, reflecting on the fact that many South American animals today are not seemingly bizarre like Australian animals. Instead, they share many similarities with species found in North America. Have the students record their responses as a journal entry for homework.



Evaluation

These activities lend themselves well for assessing student understanding. After completing all three activities, the students should turn in their maps and journal responses. If miscomprehension is evident in a student's responses, look at their maps to locate the source of confusion.

Conclusion

The fact that nearly half of the families and genera now on the South American continent belong to groups that emigrated from North America during the last 3 million years demonstrates the importance and relevance of the Great Biotic Interchange (Marshall 1998). Not only is the topic interesting, but it also addresses multiple milestones for sixth grade learning as laid out by the NGSS. The activities described can serve to introduce students at this age level to interdependent relationships in ecosystems (MS LS2.A) and ecosystem dynamics, functioning, and resilience (MS LS.C), making it an ideal lesson plan for teachers.

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