A Conceptual Model for the Study of Biomes

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Most general biology courses at secondary schools and colleges have a unit of ecology on the distribution of life types on earth. This usually includes an investigation of the world's major biomes. For purposes of this discussion, a *biome* will be defined as a major geographical area of the world for which its climate supports characteristic and predictable life types. The primary objective of instruction on biomes is to have students relate the climatic factors in these geographical areas to the kinds of life that will be supported by a given climate. The two major climatic variables of concern are *precipitation* and *temperature*.

However, an understanding of the general *patterns* of biome distribution on earth can make such a study more conceptual and meaningful. Therefore a model which relates the relevant variables and which reveals global distributional patterns can be a highly useful teaching tool. This article is about a conceptual model for teaching about world biomes.

A model for predicting the characteristics and distribution of biomes of the world based upon three critical variables was developed as a research tool and published by Holdridge in a 1947 issue of *Science*. It has appeared frequently in ecology textbooks over the years. The original model contained four variables: annual precipitation, temperature, latitude, and evaporation rate; it was quite complex. (Temperature and latitude are, of course, closely correlated.) The author developed a modified version of this for use with an interactive computer/videodisc software lesson on biomes of the world to be used in introductory biology (Leonard and Boohar 1984). The new model was validated with climate data from more than 50 widely diverse cities in the world. The variables of this new model are: *biome type, latitude, mean annual biotemperature*, and *mean annual precipitation*. The world biomes represented are *tundra, taiga, mid-latitude desert, brush, temperate grassland, temperate (deciduous) forest, tropical desert, tropical grassland, tropical (deciduous) forest*, and *tropical rain forest*.

Components of the Model

This model (shown in Figure 1) takes the geometric form of an equilateral triangle with three dimensions, each dimension represented by one of the sides (axes) of the triangle. The bottom axis, is cumulative annual rainfall which ranges from 0 to 5000 mm of rain per year. This represents the total amount of rainfall for any given area in the world for a one-year period averaged over many years. The left end of this horizontal axis represents very dry climates (deserts). Precipitation increases to very wet climates at the far right side, such as a tropical rainforest. Note that the scale for annual rainfall is not arithmetic, but has been made incrementally geometric to produce a symetrical model.

The left vertical axis represents latitude on the earth. The very bottom line would represent 0 degrees latitude or the Equator, and positions upward from that line represent latitudinal distance North or South of the equator. The point at the very top of the line represents the North or South poles. The distance between 0 and 15 degrees would be considered tropical, from 15 to 30 degrees is warm temperate or semi-tropical, from 30 to 45 degrees is cool temperate or mid-latitude, from 45 to 60 degrees is cold, from 60 to 75 degrees is frigid, and the remainder (polar regions) is ice.

Biotemperature is represented by the right vertical axis. *Biotemperature* is defined as the temperature of the plant organisms in an environment, not the air or outside sun temperature. Biotemperature is much more stable than air temperature. These are average daily temperatures computed as follows: The high for a day and the low for a day are averaged and these values are again averaged across all the days of the year. This of course, does not illustrate ex-

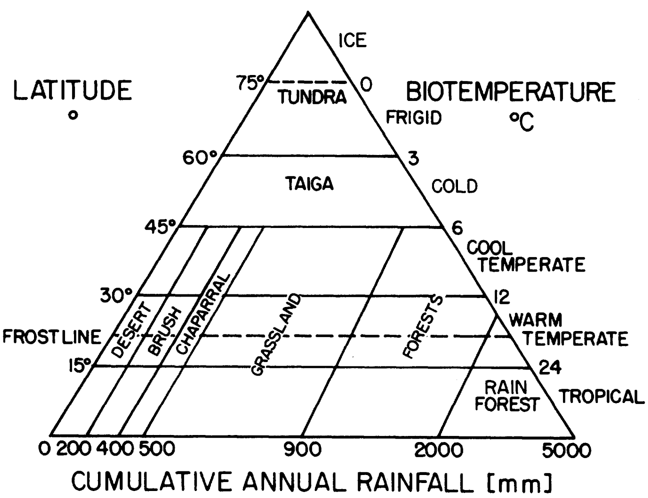

FIGURE 1. A conceptual model of world biome distribution illustrating the variables of cumulative annual rainfall, latitude, and mean biotemperature.

treme temperatures such as a summer day in Death Valley (frequently 50° Celsius) or a winter night in Fairbanks (−60° C.). The points on this axis range from the very warm environments (tropics), to the very frigid tundra and permaice.

The dotted line about a third of the way up from the bottom of the model represents the frost line or the latitude and temperature line above which freezing is likely to occur. This is important because freezing temperatures essentially curtail plant growth and photosynthesis, which, in turn, will have a great effect on the amount of food available for consumers and is a major determinant in the life types able to survive in a given biome.

The diagonal lines up to 45 degrees latitude within the triangle represent the divisions between the major temperate and tropical biomes of the world. The top half of some of the model is taken up by the two colder biomes, taiga and tundra. The permaice areas are technically not a biome because significant producers are simply absent.

Ways to Use the Model in the Classroom

This model can be used in a number of ways. If the temperature and the cumulative annual rainfall of a given geographical area are known, the student can predict what biome occupies that area by finding the point where those values intersect. Similarly, the student can identify which biome occupies an area of the world with a given annual rainfall and a latitude. Another way the student can use the model is to find the temperature range or annual rainfall if the name of the biome is known. Finally, this concept model can help determine relationships between the biomes based on the contributing variable: temperature or latitude, and precipitation. For example, the student is able to visualize that chaparral and grassland are more closely related climatically and biotically than, say, chaparral and forest. The student can visualize why, below a certain temperature, differences in rainfall are not very significant in determining the biome (taiga and tundra). Also, the student can visualize why every set of climate data will not necessarily fit clearly into a specified biome if those data lie on a border between two or more biome areas.

The BSCS Green Version text has a nice paper and pencil activity on biomes where the student plots and studies a variety of climatograms (histograms showing rainfall and temperature patterns in a specific city over a year) and tries to relate these to specific biomes. Although I have used the BSCS biome activity for many years, I have always felt it lacked a conceptual tie. I feel that this conceptual model for the study of biomes will help the student sort through climatograms which, at first glance, appear to fall into more than one biome. Also, there is an optional part of the BSCS activity which has always been unnecessarily difficult to my students, where the students are given climate data for three cities representing a North-South line running through central United States and are asked to hypothesize which biomes best fit these climatograms. Austin, TX, Kearney, NE, and Laramie WY, it turns out are all grasslands in spite of some very significant differences in their climates. The objective of this optional part of the BSCS activity, of course, is to illustrate transition biomes and differences within a biome. But the students often do not see these relationships. I feel the biome concept model will make exercises, such as this last case, much more meaningful to students because they can see the positions of these climatograms on the model in relationship to each other and in relationship to other biomes.

Possible Classroom Activities

Students can be given a paper copy of the model or the model can be made into a slide or overhead projection transparency and shown on the wall or screen. Students then can be asked to study the model while you (or they) read a description of the perimeters of the model and how to use the model (such as the description given above). Alternately, you can ask the students to try to explain the perimeters of the model and ways to use it just from an examination of the model. Then students can be asked to respond to a wide variety of questions about the model, such as the following:

1. Within which degrees latitude are the tropical climates found?
2. What is a term used to describe temperatures at 60 to 70 degrees North and South latitude?

3. What is the name of a biome which is temperate, but which has only 45 mm of rain in an average year?
4. What biome has the largest range of annual rainfall?
5. What would be a good title for the area on the model above or below 75° latitude?
6. The savanna is the name of a specific biome which has tall grasses, scattered trees, and large animals such as giraffes, zebra, hyena, wildebeast, and lions. Where do you suppose the savanna would be positioned on this concept map?
7. At least two kinds of forest biomes (other than rain forests) can be identified. One loses its leaves during the cool season and the other loses its leaves during the warm season. Suggest more specific names for these biomes and identify where each would exist on the earth.
8. Which of the lines on the model would correspond to the "timberline" observed as one goes up a large mountain?
9. What other relationships from this model can be applied to the biotic zonation of a mountain due to the altitude factor?

This model also could be used in conjunction with a study of a map of world biomes such as found in most general biology textbooks. Questions could be asked relating both the concept model and a biome map of the world.

Conceptual models can be useful teaching tools because they can elevate the instructional process beyond that of facts and memorizing to that of understanding biological concepts and the relationships between certain concepts. A model such as the one offered here can allow the biology student to explore "Why" and "How" questions in addition to the "What" questions. These additional instructional options not only make learning biology more fun and interesting, but also will facilitate long-term retention and usability of a biology education experience.

References

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