Lesson 5: Overview

This lesson include the second half of the Where's Waldo Signal vs. Noise activity as an intro. The other two activities include a review of the climate science history reading, and an activity bringing together a lot of what the students have learned with the Whittaker diagram.

Key Ideas

- **Activity 1: Signal vs. Noise; Where's Waldo likely to be?**

  This is the conclusion of the Signal vs. Noise series, and the second half of the Where's Waldo two-part lesson. In this activity, students will get an idea of how science practices can be applied to everyday questions and endeavors, like solving a Where's Waldo puzzle.

- **Activity 2: What's causing the change?**

  This activity, which is primarily a lecture, reviews the reading on the history of climate science, and has students discuss the reading and its implications. By the end of this activity, students should have a basic familiarity with the history of climate science, what the greenhouse effect is, and how we know that humans are behind the current increase in global temperature.

- **Activity 3: Biomes and Bioindicators**

  This activity covers the idea of bioindicators. It is a follow-up for Activity 1 of Lesson 2, and it is designed to allow students to have more time to think about the concept of bioindicators and the relationship between temperature, water, and wildlife. This activity is designed to help lay the groundwork for Lesson 5, and for the field work ahead.

Materials

- Student sheets
- Writing utensils
- Rulers
- Internet access

Students should be prepared to take notes, either in notebooks or on the computer.

Activity 1: Signal vs. Noise; Where's Waldo likely to be? [10 minutes]

Context for the Teacher

This activity wraps up the Signal vs. Noise series with an analysis of 68 Where's Waldo puzzles that gives us a better idea of where to expect Waldo to be. The goal of this exercise is to once again drive home the point that the larger the data pool, the more likely we are to find a clear pattern which can help us see what's going on in the world around us.

Flow of the lesson: Divide the class into small groups. Have each student look at the answers they gave to the last two question of Activity 1, Lesson 1 - Based on the Where's Waldo puzzle you were looking at, would you be able to predict Waldo's location in other puzzles? What would you need to make that prediction?

Flow of the activity

This is a small group activity.

a. Have the groups discuss their answers

Based on what you've learned this week, is there anything you would change about your answers? If so, write down those changes, and why they are good changes to make.

b. Now, have them look at Figure 1. A writer at Slate.com did an analysis of 68 Where's Waldo puzzles, marking each location in an empty space with the same dimensions as the puzzles. Have them discuss:

Looking at this plot, do you see any patterns that might help you predict future Waldo locations?

Note to teacher: You can either use a projector to display Figure 2, or print off one copy per group to hand out at this point. Look at Figure 2. The author's analysis shows that 53% of Waldos counted could be found in the two 1.5" red strips, one 3" from the bottom, and one 7" from the bottom.

Continuing small group discussion

- These data clearly won't give us Waldo's location 100% of the time, but do we have a better idea of where Waldo is likely to be?
- How would having this knowledge be useful if presented with future Where's Waldo puzzles?

Whole group/conclusion

In this case, a thorough analysis didn't give us results that can predict an outcome 100% of the time. What it DID do, however, is make it much easier to find the signal, both by showing us where it's likely to be in slightly over half the cases, *and* by allowing us to quickly eliminate the more likely locations in a systematic manner.

Even without 100% accuracy, using a large dataset to analyze what's going on can make a huge difference.

Activity 2: What's causing the change? [15-20 minutes?]

Context for the teacher

This activity is meant to review the reading on the history of climate science, and to cover the basics of the greenhouse effect, and how we know human carbon emissions are causing the temperature to rise.

Flow of the activity

This is a whole-class activity. Questions are on the student sheet.

This activity has two parts. The first is a brief review of your reading assignment from the last night, covering the history of climate science. You can think of this as an open-book quiz, that students are allowed to help each other on.

The second, which leans more heavily on teacher guidance, is to work through the implications of the discoveries made by Fourier, Tyndall, and Arrhenius (along with others). As you go through this activity, it may be useful to have the reading assignment on hand to refer to. There are some suggested questions for students built into the lecture content, if you feel they would be useful and have time to use them.

Part 1: Reading review

Fourier discovered that the amount of solar energy that hits the earth isn't enough to keep the planet above freezing by itself. What hypothesis did he form to explain Earth's temperature? (*Two possible answers – Radiation from other stars [did not turn out to be true] and some insulating capacity in the atmosphere*)

- Who discovered the evidence to support Fourier's hypothesis, and what was that discovery? (*John Tyndall, greenhouse gasses*)
- Who calculated how much we would warm if CO_2 levels doubled, and how much was that? (*Svante Arrhenius, 5-6˚C*)
- What is Charles David Keeling known for? (*The "Keeling Curve" – graph of CO2 levels over time*)

Part 2: Finding the human fingerprint on global warming.

At this point, it's good to remind students that sometimes "I don't know" is the best answer, because it tells you your next step – go find out.

The first question is: Is the warming that we have seen so far being caused by the rise in CO_2 levels?

We know from the reading that CO_2 acts as insulation, trapping heat like a jacket around the planet. There are a couple ways to check whether that is how we're being warmed, that rely on that similarity.

Note for teachers: If you have time, this next bit can be framed as a discussion.

Imagine that you put on a jacket before going outside in the winter, but it's colder than you expected it to be, so your jacket isn't thick enough.

- Would you get really cold right away? *(no)*
- Would you get cold faster or slower than if you had no jacket at all? *(slower)*
- And when you go inside, after getting really cold, do you warm up right away, or does it take time for you to get hot enough that you need to take off your jacket? *(takes time)*
- Does you jacket keep the heat indoors from reaching you as fast as it would if you didn't have a jacket on? *(yes)*
- Moving to how Earth deals with temperatures, what time of day is usually the coldest, and why? *(night, Earth blocks the sun from heating our area)*
- So if Earth has a thicker "jacket" of CO_2, what change would we expect to see in night-time temperatures? *(they would get warmer – hold on to the day's heat better)*

Take a look at Figure 2, showing the change in night time and daytime temperatures over time:

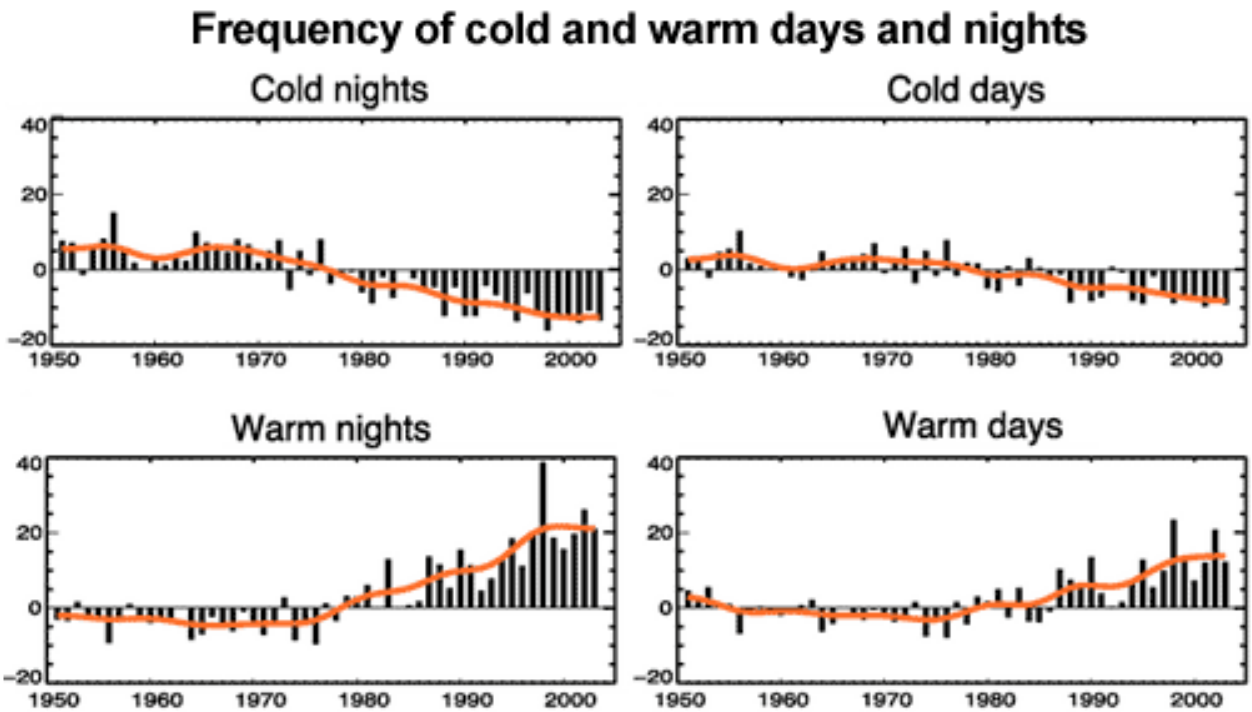


Figure 3

- Which is warming faster – nights or days? *(nights)*
- Does this support the CO_2 "jacket" hypothesis? *(yes)*

So, we know what's causing the warming, but do we know it's from humans? Where is that CO_2 coming from? Well, if it's coming from humans, then it's coming from the carbon we burn, primarily from fossil fuels (though slash-and-burn forest clearing is also a big source). Burning this stuff combines carbon with oxygen to form CO_2

Questions for students: Where does that oxygen come from? (*answer – the atmosphere*)

If the increase in CO_2 levels is caused by burning fossil fuels, then what other changes would we expect to see in the chemistry of the atmosphere? (*answer – a decrease in oxygen levels that matches the increase in CO2*)

Figure 1 shows us what changes have been measured:

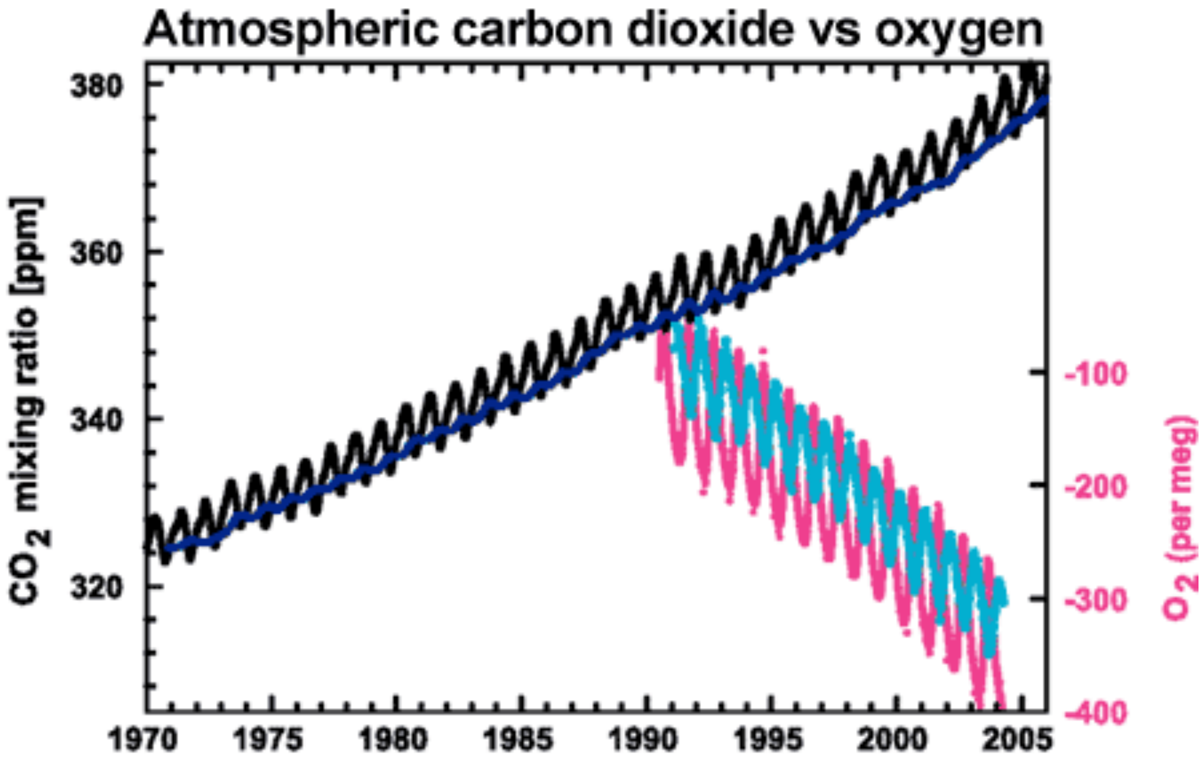


Figure 4: CO_2 concentrations from Mauna Loa, Hawaii (black) and and Baring Head, New Zealand (blue). In bottom right corner is atmospheric oxygen (O2) measurements from Alert, Canada (pink) and Cape Grim, Australia (cyan) ([IPCC AR4 2.3.1] adapted from [Manning 2006]).

Question for students:

Does the information in this graph help us understand what's causing CO_2 levels to rise? (*answer – yes, it indicates that the additional CO2 is from burning something – fossil fuels*)

Now for the last check. The sun is Earth's major heat source, and so if there's a rise in temperature, it's natural to want to see if it's caused by the sun. Fortunately, there's an easy way to tell whether an increase in temperature is coming from an increase in insulation (the CO_2 jacket), or from an external source of heat like the sun.

Imagine you're wearing a jacket, and you're still feeling a bit cold, and someone lights a great big bonfire right next to you.

- Which part of your jacket would warm up first? *(outside)*
- Now imagine that instead of lighting a bonfire, you magically added a layer of long underwear underneath the jacket you're already wearing. That would trap more heat inside the jacket with you, warming you up, but what would happen to the outer-most layer of the jacket? Would it stay the same temperature? Would it

warm up? Would it cool down? *(it would cool down because the long underwear doesn't let as much heat reach it)*

- So if CO_2 was responsible for the warming, by acting like an extra layer to the "jacket" of Earth's atmosphere, what changes would we expect in the outermost layer of Earth's atmosphere?

Figure 3 shows the results of measurements taken between 1980 and 1995 at different elevations in Earth's outer atmosphere, from 50km (farthest out) on the upper left, to 22km (closer, but still upper atmosphere) at the lower right.

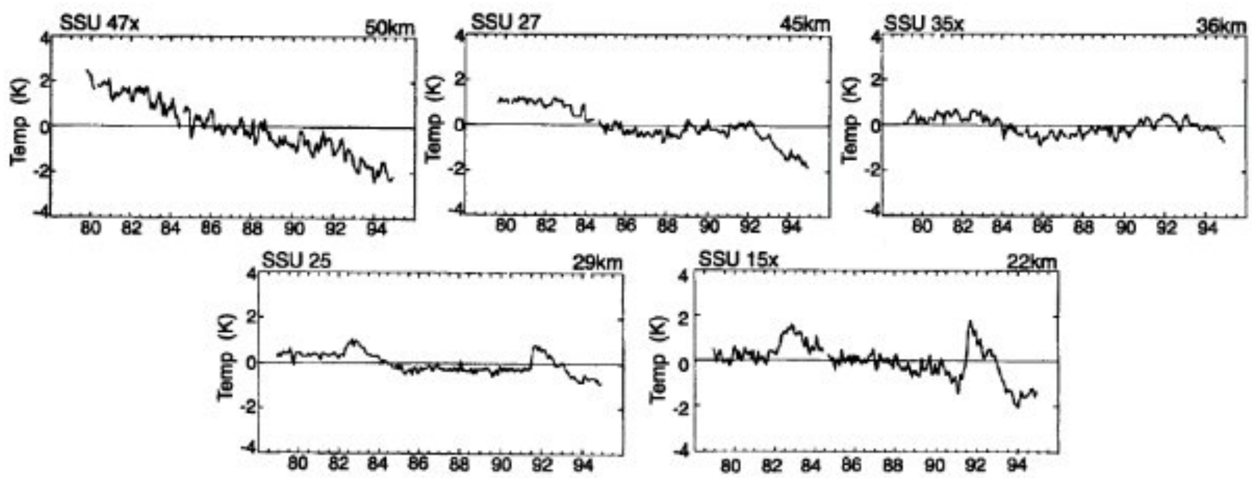


Figure 5– Stratospheric Temperatures over time at different elevations

- Do the data represented here support the hypothesis that CO_2 is warming the Earth by insulating it, and trapping more heat? *(yes)*

Activity 3: Biomes and Bioindicators [10-15 minutes]

Context for the teacher

This activity is designed to reinforce the lessons of the Whittaker Diagram and the plant range shift activity in Lesson 2. It should give students a feel for the processes scientists go through in figuring out how to find the answers to their questions. For this activity you and the students will look up climate data for assigned locations on Wikipedia.

Flow of the activity:

This activity starts with the whole class, then moves to small groups.

Distribute worksheets, copies of the Whittaker diagram and location assignments to the class, with one location assignment per small group.

Give a short introduction reviewing past content and preparing them for this activity. Points to cover:

- It can be hard to pick the climate change signal out of the noise of natural year-to-year changes.
- Certain species may start responding to changes before scientists can say the changes are happening with a high degree of certainty.
- Bioindicator species are chosen as “measuring tools". It is good to revisit briefly some of the organism responses encountered in earlier lessons: the plants, the birds, the butterflies. What environmental changes were these organisms responding to, and how did they respond?
- Go through the worksheet for Plymouth for the whole class first (they don’t need to fill one out themselves for this), as an example of what they’re going to be doing. The aim will be to place some specific locales on the "map" of the Whittaker diagram and then use that to reason about how predicted climate changes will affect the organisms in that locale.
- In filling out the last question, the goal is not to name particular plants or animals, but rather to describe in very simple terms the characteristics we’re looking for – based on changes in their seasonal behaviors driven by a change in climate, or on a particular sensitivity to precipitation or temperature changes which make their habitat less hospitable (either for themselves or for organisms they depend upon).

  Once you’ve done that, have the small groups perform the same exercise for the locations you've assigned to them using Wikipedia to get the data they need.

Suggested locations include: Kabul, Afghanistan; Cairo, Egypt; Dalanzadgad, Mongolia; Boston, MA, U.S.A; Phoenix, AZ, U.S.A.; Glasgow, Scotland; Dar es Salaam, Tanzania; Capetown, South Africa; Bath, Maine; Pyongyang, North Korea;

NOTE: Either at the end of the lesson, or during this activity, students should be reminded that this activity only covers two factors in a very simplistic manner. For example, it doesn't tell us WHEN the yearly precipitation falls. If it all comes in about a month or two, then we tend to find a much drier biome.

Student Name_________ Teacher Name_____________ Date_______

Instructions: Please go through this sheet and fill out the answers by discussing them with each other, and by using the Whittaker diagram and the Wikipedia page for your location. For questions 1, 3, 4, and 5, mark the answers on the diagram and label them with the appropriate question number. Use the Celsius and metric scales.

Location:
Current average annual high and low temperatures:
Current average annual precipitation (cm):

1) **Biome/place on the Whittaker diagram:**

2) **Location within that biome - what other biome(s) is the location nearest to?**

3) **100 years ago, global average temperature was about 1˚C lower than it is today.**
Assuming that the increase in temperature is the only change, where on the Whittaker diagram did your location fall 100 years ago?

4) **The mid-range estimate for warming by 2100 has the planet adding another 2.5˚C. Where does that put your location on the Whittaker diagram?**

5) **If you have a dry location, it's likely to get drier as the climate warms, and wet locations are likely to get wetter. Depending on which you have, where does an increase or decrease of 10cm precipitation per year move your location?**

6) **What are some characteristics of organisms that would make good indicator species**? *(Hint:* It depends a lot on what you're trying to measure.*)*

Note for teachers: This last question is intended to be difficult. Guide students to think about characteristics like sensitivity to changes in precipitation or temperature, or regular seasonal behaviors like migration in birds, or flowering times in plants.

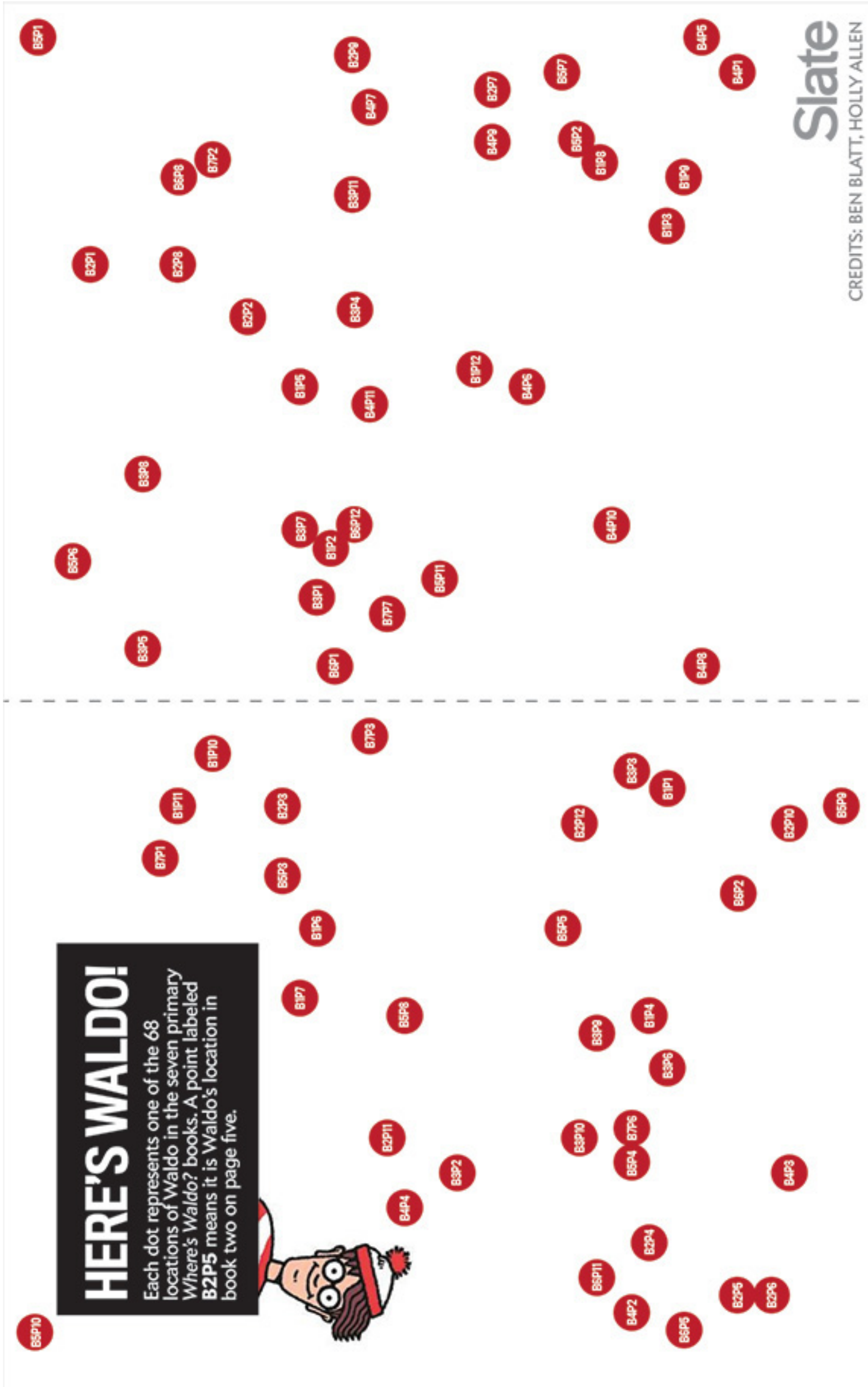

HERE'S WALDO!
Each dot represents one of the 68 locations of Waldo in the seven primary Where's Waldo? books. A point labeled B2P5 means it is Waldo's location in book two on page five.
Slate
CREDITS: BEN BLATT, HOLLY ALLEN

Figure 1

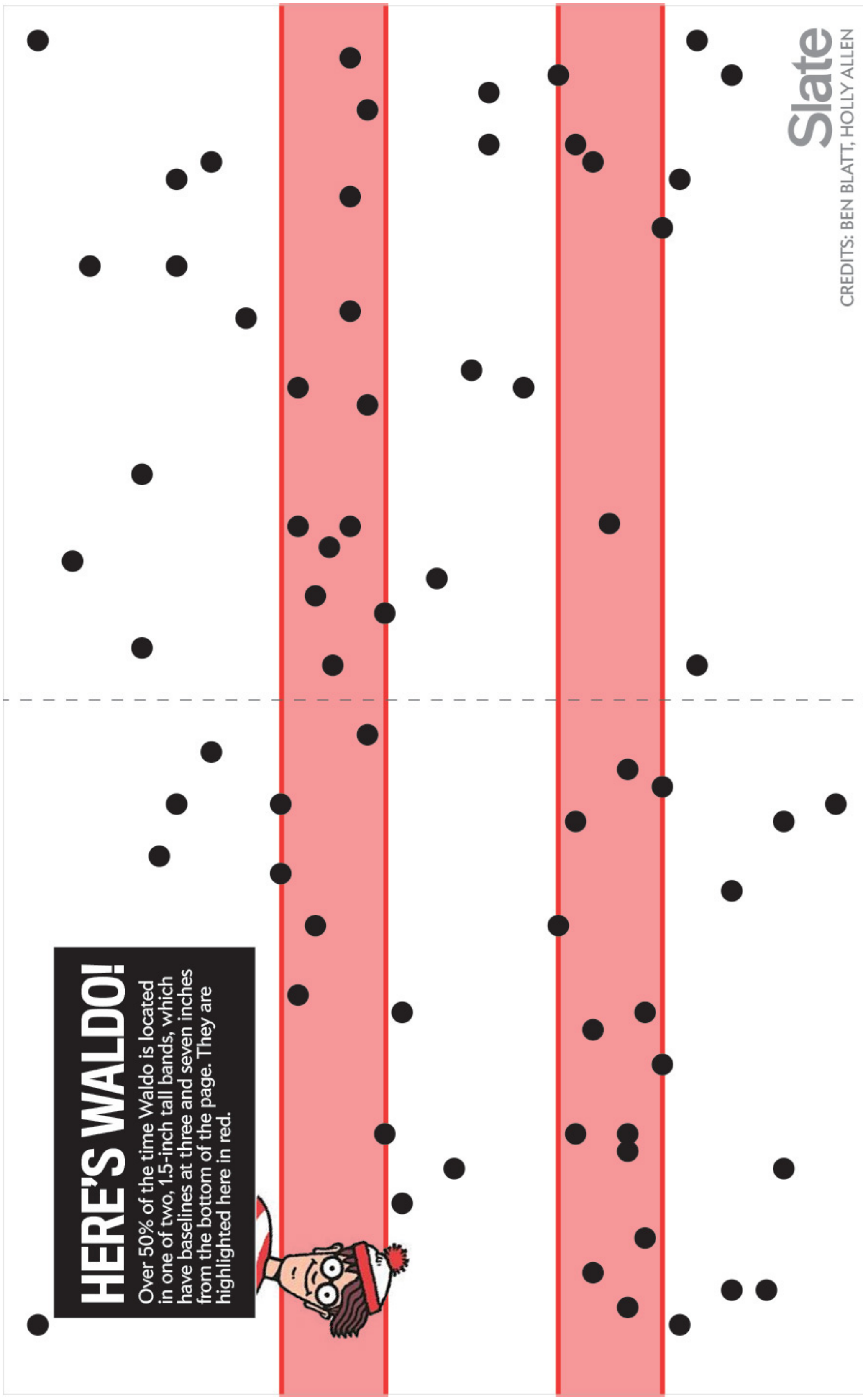
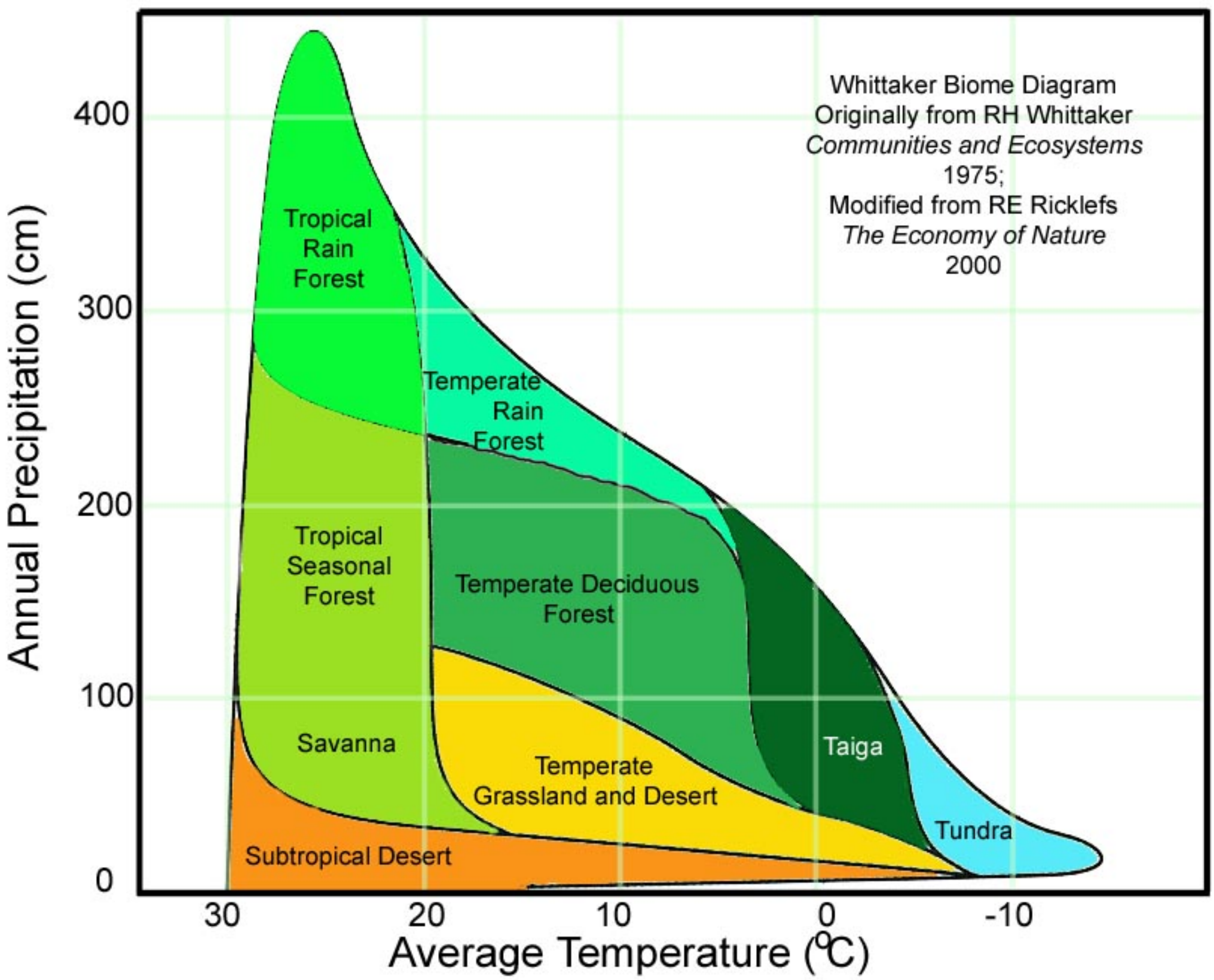

HERE'S WALDO!
Over 50% of the time Waldo is located in one of two, 1.5-inch tall bands, which have baselines at three and seven inches from the bottom of the page. They are highlighted here in red.
Slate
CREDITS: BEN BLATT, HOLLY ALLEN

Figure 2


Whittaker Biome Diagram
Originally from RH Whittaker
Communities and Ecosystems
1975;
Modified from RE Ricklefs
The Economy of Nature
2000
Annual Precipitation (cm)
400
300
200
100
0
30
20
10
0
-10
Average Temperature (°C)
Tropical Rain Forest
Temperate Rain Forest
Tropical Seasonal Forest
Temperate Deciduous Forest
Savanna
Taiga
Temperate Grassland and Desert
Tundra
Subtropical Desert

Lesson 5 Review and Vocabulary

Context for the Teacher

These are questions and terms you may find useful either for homework, for reviewing the lesson, or as part of a review of the whole unit for the students. Use them or not as you see fit.

Review Questions

- When you are testing a hypothesis, is it better to gather as much data as possible, even though that data indicates that you might be wrong, or to only look for data that would indicate you might be right?
- What did Joseph Fourier discover about Earth's climate?
- What did John Tyndall discover about Earth's atmosphere?
- What did Svante Arrhenius discover about how changes in "greenhouse gasses" could affect Earth's temperature?
- What are three "fingerprints" that show us human activity is responsible for the rise in CO_2, and for the rise in temperature?

Vocabulary

Greenhouse Gas: An atmospheric gas that absorbs heat, and then releases that heat in all directions, acting as insulation for the planet.

Indirect measurement (sometimes referred to as a "proxy measurement"): Indirect, or proxy measurements are a way to get information about things that are difficult to measure, by measuring how they affect something else. One example would be measuring the amount of water that's typically available in an area by looking at the plant species living there. If you know which plant species need how much water, then you can get a good idea of water availability from the local ecosystem. Cattails would mean lots of water, cactus would mean very, very little water.