Encyclopedia of Life
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iNaturalist City Nature Challenge: Introduction to Biodiversity

Big Ideas
- Biodiversity and Society
- Citizen Science and Open Science
- Science Practices and Skills

Essential Questions
- **How many** different species are on Earth and how do we **find** them?
- What are the **benefits** and **limitations** of iNaturalist to observe/measure global biodiversity?
- How do organisms **interact** with each other and humans in urban ecosystems?

Objectives
Cognitive (What content knowledge will students understand?)
- Students will **understand** biodiversity at a **high level**
- Students will **compare and contrast** global biodiversity at different scales
- Students will **describe** that organisms can be classified with taxonomic systems based on their characteristics and genome sequences
- Students will **explore** the diversity of terrestrial, freshwater, and marine ecosystems in the Greater Boston area, including urban habitats
- Students will **identify** local examples of different taxa
- Students will **understand** that their community is also home to a great diversity of organisms

Skills (What skills will students practice?)
- Students will **observe** differences in organisms that they name across the tree of life
- Students will **hypothesize** the numbers of species of plants, animals, fungi, and other organisms

Affective (What will students feel?)
- Students will feel **humbled** by the biodiversity across the world and in their local ecosystems
- Students will feel **empowered** to observe and document local species as part of the City Nature Challenge

Grades: 9-12 Time: 30 minutes Location: Classroom

Materials
- Tape
- Paper that can be hung/taped around the room (OR) Whiteboard
- Markers or colored pencils (multiples of colors, e.g. 6 red, 6 green, 6 blue)
- Pie charts (attached)
- Biodiversity worksheet and key (attached)

- BioBlitz card deck (download here: http://education.eol.org/species_cards/bioblitz.pdf)

Directions

Preparation

Prepare posters (post-it paper, butcher block, or other paper) with the name and an EOL Species Card for each (optional, download here). Hang posters around the room or place on tables. Students will walk around and write and draw on posters.

Engage

Brief introduction to iNaturalist City Nature Challenge (CNC): In a few weeks, we will participate in a 5-day biodiversity competition with 16 cities across the nation to see which group can observe the most species. We will use an online community called iNaturalist to upload our observations and investigate the results of the CNC. This project is much more than a competition, however. We will be acting as **citizen scientists** by helping to contribute data to open science repositories. Scientists across the globe can access the reliable, or verified, data we collect to use in research studies. In the next few days, we will learn all about the incredible diversity of life on our planet and the value of the data that we collect during the CNC to the scientific field.

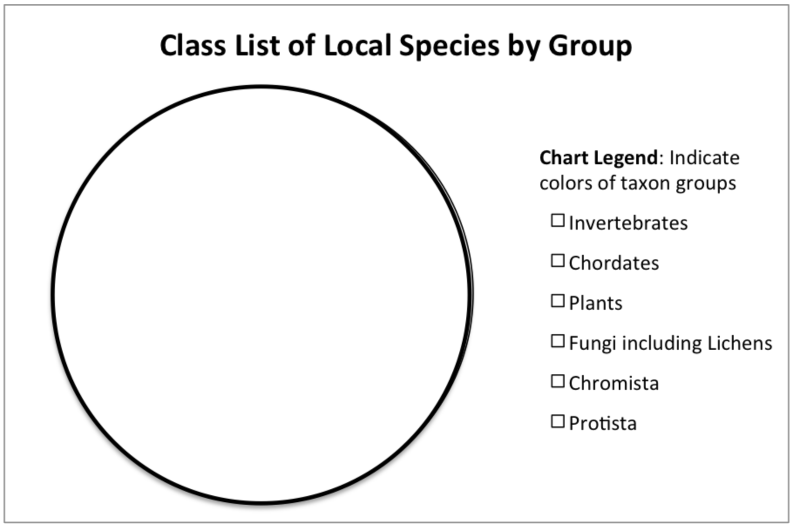
Define biodiversity: First, write the word "biodiversity" on the board. It is helpful to write the "bio" (Greek, meaning *life*) and "diversity" in two different colors. Ask students to brainstorm a definition of this word for a moment, then ask a volunteer to share one. Then explain: **biodiversity** refers to the *variety of life on earth*. The earth has an incredible amount of biodiversity across the tree of life, from bacteria to blue whales. Scientists use a system of classification called **taxonomy** to organize the millions of species in order to better understand their relationships. This system of organization involves classifying species into taxonomic groups, called **taxa** (singular **taxon**). A taxon is a taxonomic group of any rank, such as species, family, or class. We will be diving into the concept of biodiversity to explore what scientists have already discovered, the number of species they estimate exist, and the species that have been observed locally.

Recall local biodiversity knowledge: Have all students use the same color marker (green, for example) and walk around the room for a few minutes to draw or write the names of species/organisms in each taxon that they have seen or that they know lives around the [Greater Boston] region. Explain the geographic areas that will be included in the CNC, or project the iNaturalist "Place" webpage that shows the area which will be covered. Students should observe that the area includes a variety of **terrestrial**, **freshwater**, and **marine** habitats from the Blue Hills to the Massachusetts Bay. Students should try their best not to repeat organisms, but perhaps put a mark next ones they have also seen.

Review the lists and discuss:

- Which organisms occur more than once (i.e. were suggested by more than one student)?
- Does the number and proportion of student examples reflect the "true" number and proportion of species we would expect to see in the local area?
- Would we expect our examples to be accurate? Why or why not?

Optional: Have class synthesize data into a pie chart by calculating the total number of organisms/species in each taxon and creating a chart to represent the percentages they have observed or expect to live in the Greater Boston Area.



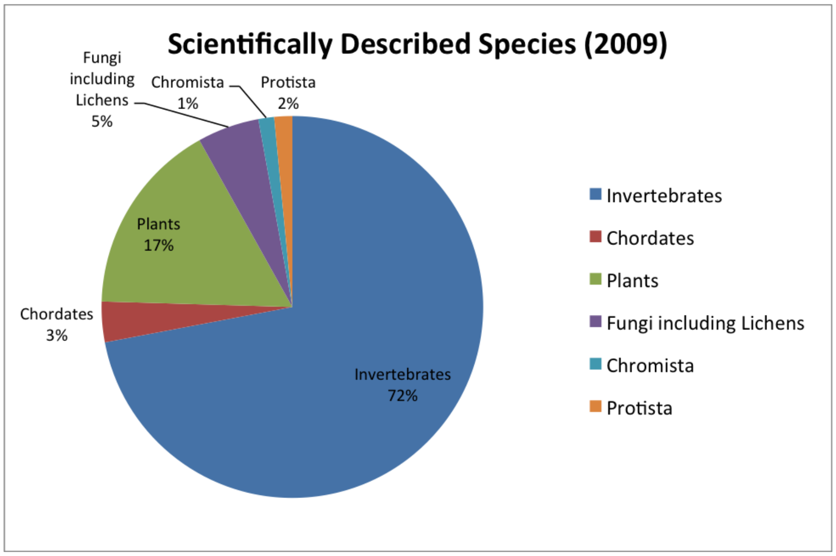
Explore

Now that students have shared their knowledge of local biodiversity, ask them to think about biodiversity on a more global scale, including oceans, rainforests, deserts, etc. There are about 1.9 million named species worldwide! The class has already discussed a few of those species. Based on the lists they created (and pie chart, if applicable), ask them to estimate how the 1.9 million species are distributed across the different taxa. Which group has the most scientifically named species? Which groups do students think might have more species than they are familiar with locally? Students should use the Global Biodiversity Worksheet in appendix.

Ask for a few students to take a guess for each group, then reveal the correct numbers (project or write on board to save time). Show **pie chart of scientifically described species** in the following major groups:

- Kingdoms: Fungi, Protista, Chromista**, Plantae, Animalia
- Phyla in Animalia: Chordata, all invertebrate groups

  **Note: Chromista is a taxonomic group that includes organisms like diatoms, kelps, and mildew. It is defined in some taxonomies. Different systems of classification exist and have different rationales for their taxa; depending on their application, different systems can be more helpful or accurate to use than others. A new system can be created by any scientist if there is data to support it.



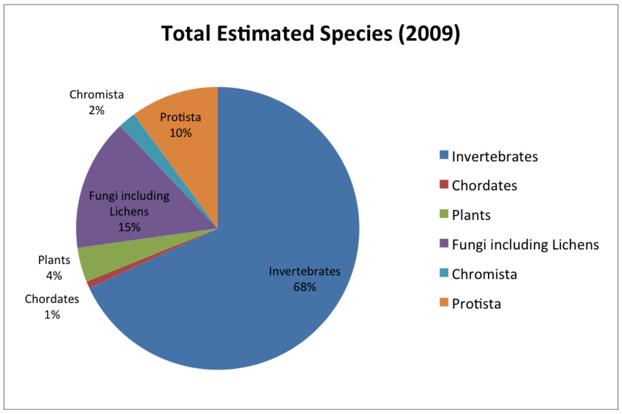
Individually, or in small groups, ask students to **compare** the pie charts for scientifically described species and students' local species knowledge. Ask students: is there are any patterns among the numbers they hypothesized and the number of local species they knew in each group?

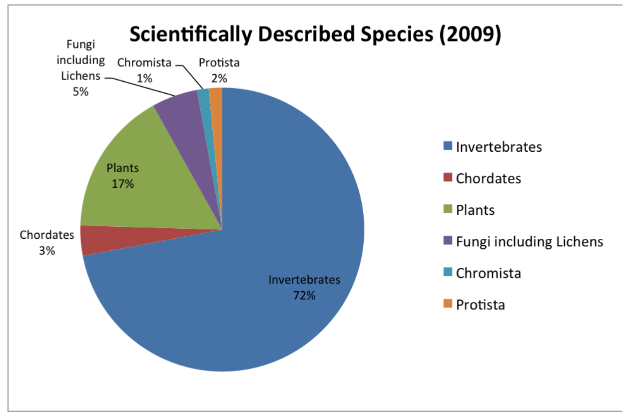
Explain
Biodiversity is a concept that describes the variety of living things that exist across a wide spectrum. Some are tiny, like bacteria. Some are huge, like blue whales (the largest animals known ever to live on Earth) or clone trees with interconnected roots (Pando, Fishlake National Forest, Utah). As mentioned earlier, there are 1.9 million named complex organisms. However, scientists estimate that humans have only described about 20-25% of the species on earth! Chapman (2009) synthesized our current understanding of global biodiversity and projections for undiscovered species. Based on review and synthesis of sources, the author estimates there are 8-10 million **complex** or **eukaryotic** species total on earth.

See the **pie chart of total estimated species**, compare to the **scientifically described species chart**. Have students analyze the charts and discuss:

> Question: From these graphs, what groups do you think scientists expect to discover more species? What information did you use to determine this?
>
> *Sample Answer: For total estimated species, the proportions of fungi and protists increased significantly, indicating that a greater proportion of these groups are likely still undiscovered. The proportion of the invertebrate group stayed relatively constant at a larger scale, but the enormous size of this group indicates there are still millions of species that are likely undiscovered. Finally, the plant and chordate "slices" both became significantly smaller in the total estimated pie chart, indicating that there are significantly fewer new species likely to be discovered. Additionally, many microorganisms are unknown, difficult to detect, and complex*

to classify. Prokaryote domains of Bacteria and Archaea are largely unknown, and because of their size and ability to mutate quickly, they are challenging to classify and differentiate at a species level.





Elaborate

The diversity of life is all around us, not only high in the canopies of the jungles or deep in the oceans. Humans have long been interested in exploring and understanding the many forms of life on earth. A type of sea slugs called *Aplysia* were some of the earliest animals to be mentioned in literature when described in Pliny's *Historia Naturalis* in 60 A.D. Since that time, naturalists, artists, scientists, and writers have been describing organisms and collecting specimens from the far reaches of the planet. These historical descriptions and specimens are essential to our understanding of biodiversity. Advances in molecular science and technology have given us even more tools to create enormous networks and communities of naturalists and scientists to share observations without needing to collect and store specimens.

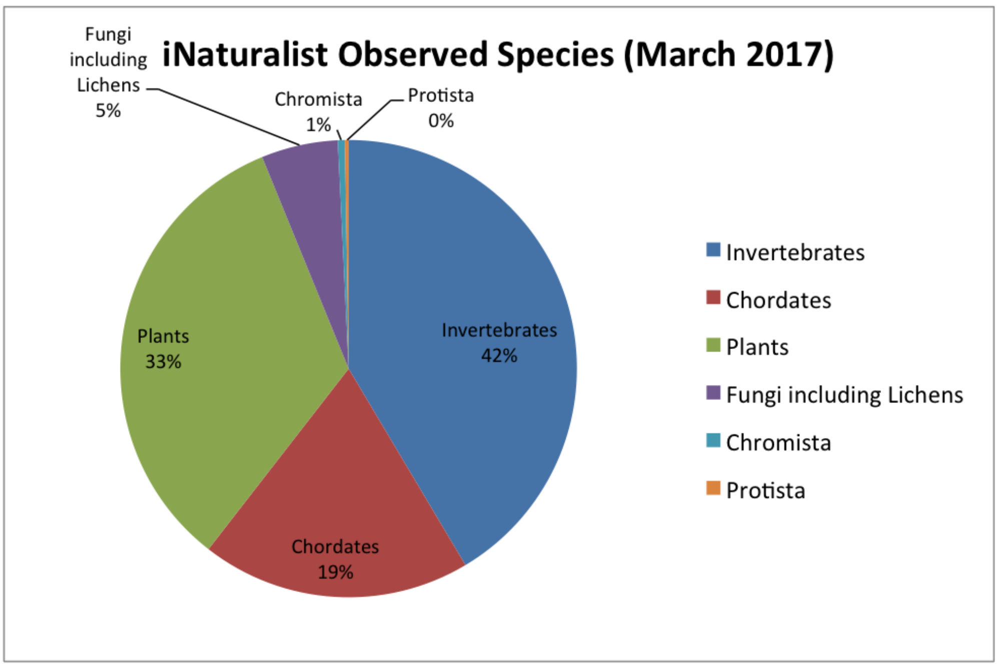
iNaturalist.org is an online observation platform in which users can document observations of biodiversity and share with a community of enthusiasts and scientists. Project iNaturalist.org/observations and display a map of observations and statistics. As of March 6, 2017, over 89,300 observers and 17,000 identifiers (community members who help identify and/or verify observations) have contributed to iNaturalist. There have been nearly **3.74 million observations** in the last nine years. iNaturalist is an excellent tool for documenting biodiversity around the world.

Question: How many species do you think have been observed on iNaturalist from those 3.74 million observations?

Answer: As of March 6, 2017, there have been ***104,018 species documented****!*

Compared to the number of observations, the number of species is quite low! This number is also about 5% of the 1.9 million named species and 1% of the approximately 10 million species estimated to live on Earth. Have students use the following table to create a pie chart of iNaturalist observations, or show them a complete one.

Taxon Group	Species Documented
Animals: Invertebrates	43,111
Animals: Chordates	19,841
Plants	34,632
Fungi including Lichens	5,644
Chromista	514
Protista	276



<u>Compare and contrast:</u> Have the class relate this new chart to the two global biodiversity charts (scientifically described species & total estimated species). Have students work independently or in small groups to address the following questions:

> <u>Question:</u> What are the potential benefits to using iNaturalist?
>
> *<u>Sample Answer:</u> With such a huge user base of enthusiasts, naturalists, scientists, and the general public, more data can be collected by citizen scientists. We will talk about citizen scientists and how iNaturalist users contribute to scientific research in the next activity.*

Question: What patterns and differences are found between observed species on iNaturalist and globally described species?

Sample Answer: Nearly of iNaturalist observations are plants and nearly ¼ are chordates; while both groups represent small percentages of described species. Invertebrates constitute less than half of the iNaturalist observed species, but about ¾ of described species.

Question: Why are there discrepancies between observations on iNaturalist and described species? What are the limitations to using iNaturalist?

Sample Answer: There are a number of reasons for discrepancies between the iNaturalist observed species and described species.

*1) Looking at the world map on iNaturalist there are large areas of the world, especially in Africa, Asia, and parts of South America, that have not been documented at all, many of those containing **biodiversity hotspots** - places with high concentrations of biodiversity that are often threatened by human activity.*

*2) Additionally, invertebrates can be much more challenging to identify, as some species can only be distinguished from one another by their **genomes**.*

3) Finally, not all taxa have equal numbers of experts. There are a lot of ornithologists in the world that study the nearly 10,000 bird species. There are also many entomologists who study beetles, but there are an estimated 1 million species of beetles around the world. There needs to be a lot more specialists to cover that huge number. Larger animals/plants are much easier to FIND and easier to photograph. Observing and documenting some invertebrates or microorganisms on iNaturalist requires additional tools - such as microscopes, specialized cameras, and sometimes more lab equipment.

Finally, visit the observations in Greater Boston (http://www.inaturalist.org/observations?place_id=118678) on iNaturalist, which will display all of the observations that have been made within the Boston City Nature Challenge zone over time. As of March 6, 2017, users have documented **24,884 observations** of **3,027 species** in the area.

This is where the people of the Greater Boston area enter the scene. With the help of local naturalists, students and the public, we can act as citizen scientists to discover the biodiversity of urban, suburban, rural, and even marine habitats around Boston. We will also contribute to the global endeavor to document biodiversity. The data we collect may help inform scientists about the ranges and distributions of species, presence of endangered/threatened species, presence of invasive/exotic species, behaviors, adaptability of species to urban areas, response to global climate change, air/water pollution, or other human impacts.

Evaluate
Ongoing questioning about the patterns of biodiversity from iNaturalist observations compared to described species to total estimated species act as an evaluation for understanding of the concept of biodiversity at different scales.

Based on the exercises around global and local biodiversity, have students write one question they are interested in investigating during the City Nature Challenge. Consider the different groups of organisms we have discussed, habitats near their school or home, and any other personal interests. For example, students may be interested in the presence of migratory and resident birds in their neighborhood or the presence of pollinators in different habitats (school garden vs. athletic field). They might investigate what is happening with those populations during the CNC and potentially combine that with investigating any phenology mismatches.

Extend
Discuss a paper or reading about urban biodiversity; how humans and organisms coexist and depend on each other in urban habitats; or surprising species that call Boston home (endangered species, etc). Have the **focal organisms** been catalogued on iNaturalist in our area? Why do you think they have or have not been documented? Students should prepare a short essay, presentation or discussion points to share with the class.

- North Atlantic Right Whales
- Moose in Watertown, June 2016 - typical geographic range, iNaturalist observations
- Spring amphibian vernal pool migrations
    - Sightings in MA
    - iNaturalist observations

Massachusetts Science, Technology, and Engineering Standards

LS2 - Ecosystems: Interactions, Energy, and Dynamics

- HS-LS2-1. Analyze data sets to support explanations that biotic and abiotic factors affect ecosystem carrying capacity.
- HS-LS2-2. Use mathematical representations to support explanations that biotic and abiotic factors affect biodiversity, including genetic diversity within a population and species diversity within an ecosystem.
- HS-LS2-6. Analyze data to show ecosystems tend to maintain relatively consistent numbers and types of organisms even when small changes in conditions occur but that extreme fluctuations in conditions may result in a new ecosystem. Construct an argument supported by evidence that ecosystems with greater biodiversity tend to have greater resistance to change and resilience.
- HS-LS2-7. Analyze direct and indirect effects of human activities on biodiversity and ecosystem health, specifically habitat fragmentation, introduction of non-native or invasive species, overharvesting, pollution, and climate change. Evaluate and refine a solution for reducing the impacts of human activities on biodiversity and ecosystem health.

LS4: Biological Evolution: Unity and Diversity

- HS-LS4-1. Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence, including molecular, anatomical, and developmental similarities inherited from a common ancestor (homologies), seen through fossils and laboratory and field observations.

ESS3 - Earth and Human Activity

- HS-ESS3-3. Illustrate relationships among management of natural resources, the sustainability of human populations, and biodiversity.

Science Practices (MA STE)

- Asking Questions and Designing Problems
- Developing and carrying out investigations
- Analyzing and Interpreting Data
- Communicating Evidence

Next Generation Science Standards

Performance Expectations

- HS-LS2-1. Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales
- HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.
- HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
- HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

- HS-ESS3-3. Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.

Science and Engineering Practices

- Asking Questions and Defining Problems
- Planning and Carrying Out Investigations
- Analyzing and interpreting Data
- Using Mathematics and Computational Thinking
- Constructing Explanations and Designing Solutions
- Engaging in Argument from Evidence
- Obtaining, Evaluating and Communicating Information

NGSS Nature Of Science Principles (Appendix H)

- Scientific Investigations Use a Variety of Methods
- Scientific Knowledge is Based on Empirical Evidence
- Scientific Knowledge is Open to Revision in Light of New Evidence
- Scientific Models, Laws, Mechanisms, and Theories Explain Natural Phenomena
- Science is a Way of Knowing
- Scientific Knowledge Assumes an Order and Consistency in Natural Systems
- Science is a Human Endeavor
- Science Addresses Questions About the Natural and Material World

References

Chapman, A. (2009). *Numbers of living species in Australia and the world* (2nd ed.). Parkes, ACT: Australian Govt., Dept. of the Environment, Water, Heritage, and the Arts

Global Biodiversity Worksheet

Groups	Your Estimate of Number of Species	Number of Scientifically Described Species*	Total Estimated Number* (including species not yet described)	Percent of Total that are Scientifically Described
Squid, bivalves, snails (Phylum Mollusca)				
Crustaceans (Phylum Arthropoda)				
Arachnids (Phylum Arthropoda)				
Insects (Phylum Arthropoda)				
Sponges (Phylum Porifera)				
Jellies, Corals, Anemones (Phylum Cnidaria)				
Segmented Worms e.g. earthworms (Phylum Annelida)				
Sea stars and urchins (Phylum Echinodermata)				
All Invertebrates				
Tunicates (Phylum Chordata)				
Fish (Phylum Chordata)				
Amphibians (Phylum Chordata)				

Reptiles (Phylum Chordata)				
Birds (Phylum Chordata)				
Mammals (Phylum Chordata)				
All Chordates				
Algae				
Ferns and allies				
Gymnosperms (Conifers)				
Angiosperms (flowering plants)				
All Plants				
Fungi (including Lichens)				
Chromista				
Protista				
Total				

*Estimates gathered from: Chapman, A. (2009). *Numbers of living species in Australia and the world* (2nd ed.). Parkes, ACT: Australian Govt., Dept. of the Environment, Water, Heritage, and the Arts

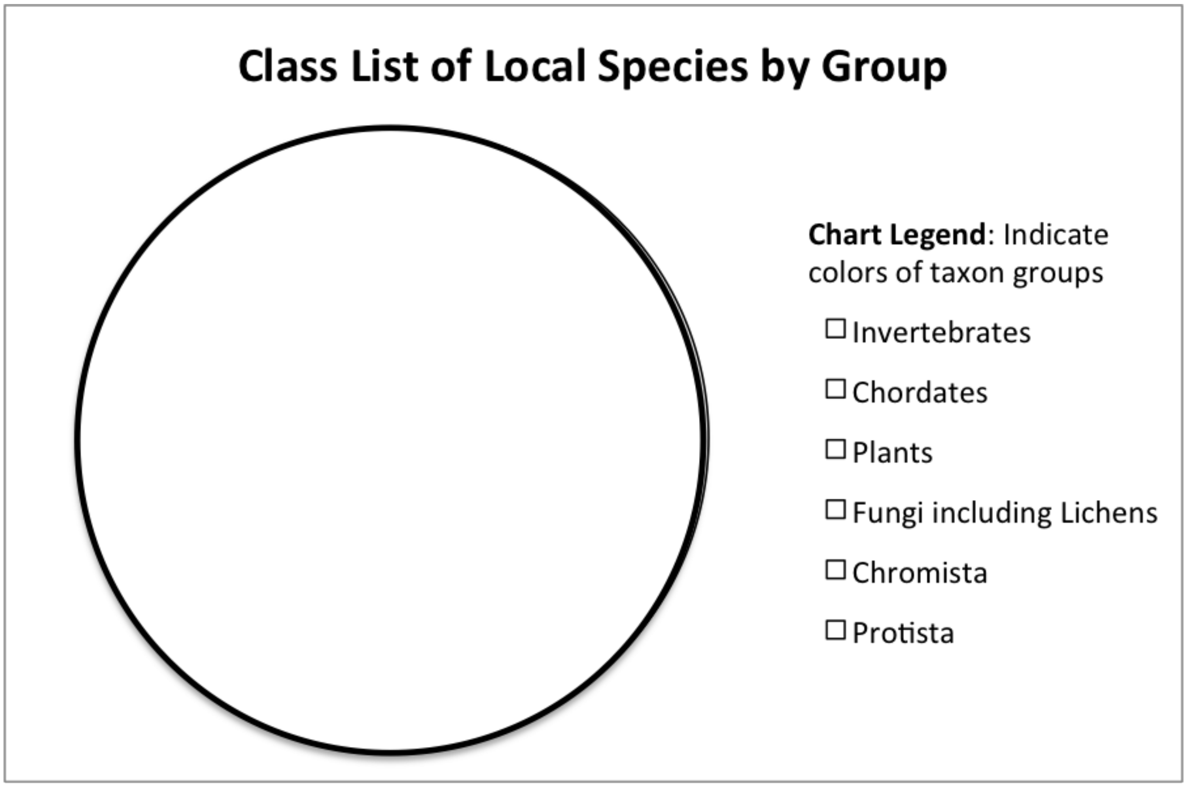
Appendix A: Global Biodiversity Worksheet Answer Key

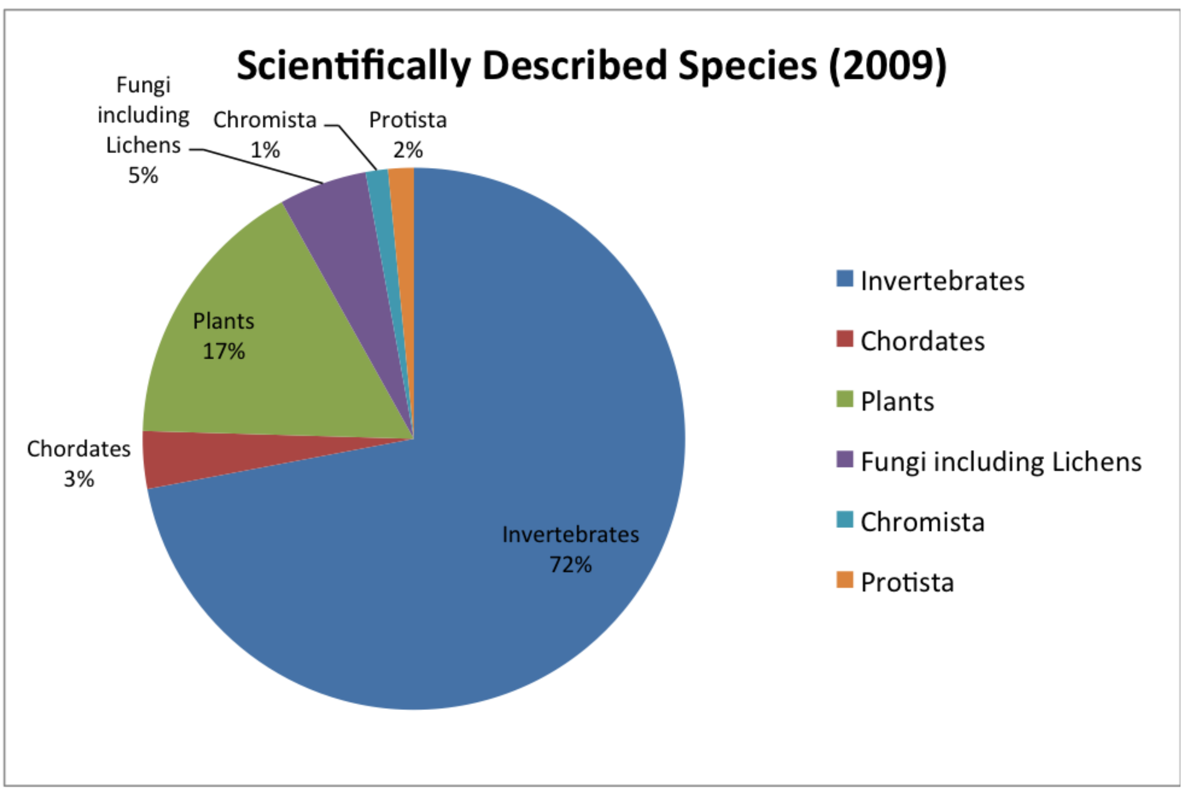
Groups	Your Estimate of Number of Species	Number of Scientifically Described Species*	Total Estimated Number* (including species not yet described)	Percent of Total that are Scientifically Described
Squid video, bivalves, snails (Phylum Mollusca)		85,000	200,000	42.5%
Crustaceans (Phylum Arthropoda) 1, 2, 3		47,000	150,000	31.3%
Arachnids (Phylum Arthropoda) 1, 2		Over 102,000	600,000	17%
Insects (Phylum Arthropoda) 1, 2, 3		Over 1,000,000	5,000,000	20%
Sponges (Phylum Porifera) 1, 2, 3		6,000	18,000	33.3%
Jellies, Corals, Anemones (Phylum Cnidaria)		Over 9,700	Unknown	Unknown
Segmented Worms e.g. earthworms (Phylum Annelida)		Over 16,700	30,000	55.6%
Sea stars and urchins (Phylum Echinodermata)		7,000	14,000	50%
All Invertebrates		**1,359,365**	**~6,755,830**	**20.1%**
Tunicates (Phylum Chordata)		2,760	Unknown	Unknown
Fish (Phylum Chordata) 1, 2, 3, 4		Over 31,000	40,000	77.5%

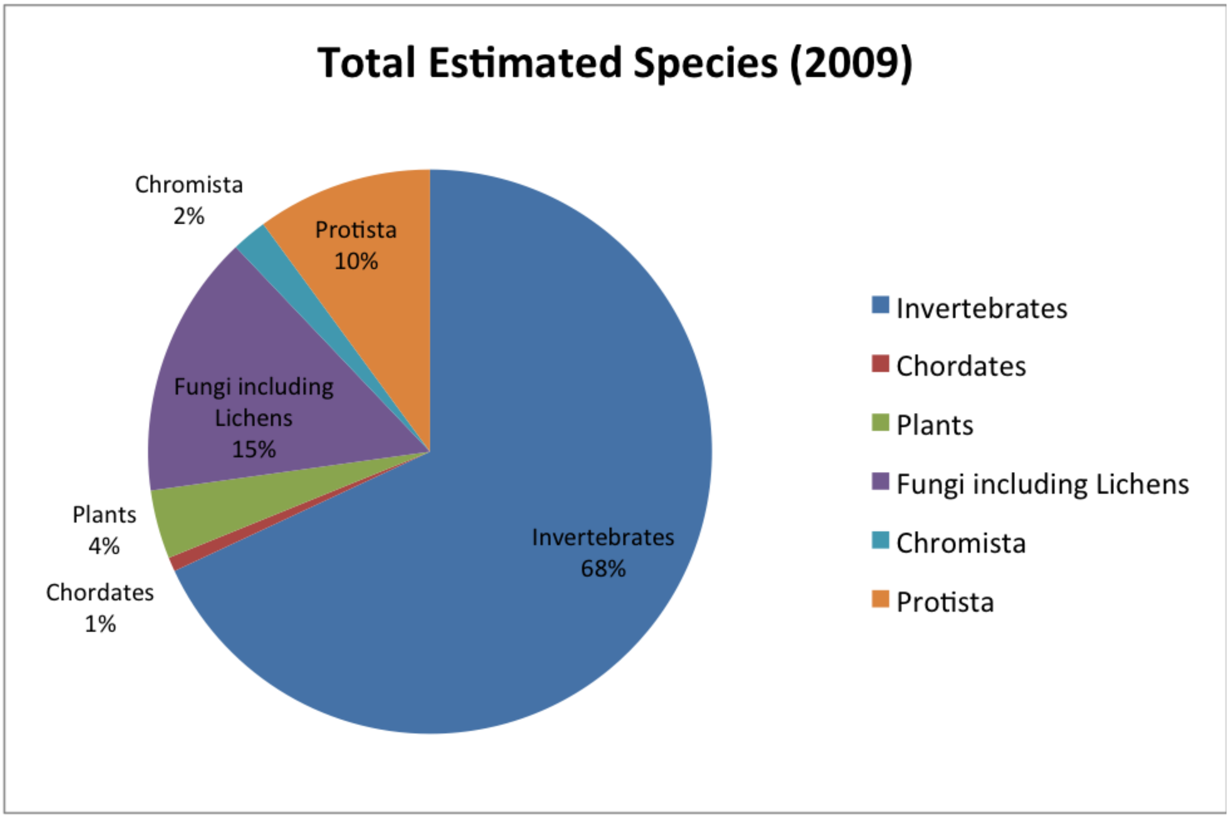
Amphibians (Phylum Chordata) 1, 2, 3		Over 6,500	15,000	43.3%
Reptiles (Phylum Chordata) 1, 2, 3		Over 8,700	10,000	87%
Birds (Phylum Chordata)		9,900	10,000	99%
Mammals (Phylum Chordata)		5,487	5,500	99.8%
All Chordates		**64,788**	**~80,500**	**80.5%**
Algae		12,272	Unknown	Unknown
Ferns and allies		~12,000	15,000	80%
Gymnosperms (Conifers)		~1,021	~1,050	97.2%
Angiosperms (flowering plants)		~268,600	~352,000	76.3%
All Plants		**~310,129**	**~390,800**	**79.4%**
Fungi including Lichens		**98,998**	**1,500,000**	**6.6%**
Chromista		25,044	~200,500	12.5%
Protista		28,871	Over 1,000,000	2.9%
Total		**1,899,587**	**~10,327,630**	**18.4%**

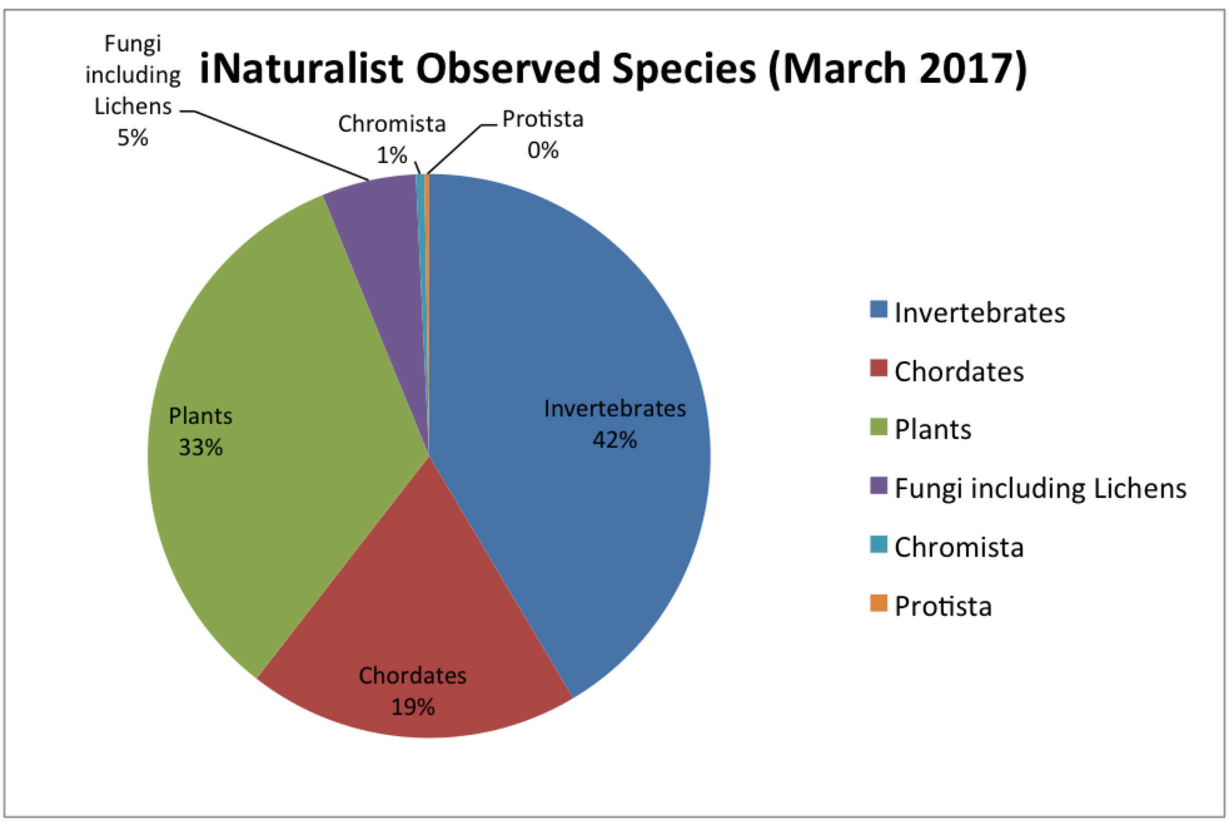
*Estimates gathered from: Chapman, A. (2009). *Numbers of living species in Australia and the world* (2nd ed.). Parkes, ACT: Australian Govt., Dept. of the Environment, Water, Heritage, and the Arts

Appendix B: Pie Charts






Total Estimated Species (2009)
Chromista
2%
Protista
10%
Fungi including
Lichens
15%
Plants
4%
Chordates
1%
Invertebrates
68%
Invertebrates
Chordates
Plants
Fungi including Lichens
Chromista
Protista


iNaturalist Observed Species (March 2017)
Fungi
including
Lichens
5%
Chromista
1%
Protista
0%
Plants
33%
Invertebrates
42%
Chordates
19%
Invertebrates
Chordates
Plants
Fungi including Lichens
Chromista
Protista