How Many Species are There?

The Continuing Challenges of Describing Biological Diversity

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WHERE DISCOVERIES BEGIN

TOWSON UNIVERSITY

Overview

- Biodiversity: What & Why?
- Species: One Component, not All Encompassing
- Global Species Estimates
- Natural History Collections and the Future of Biodiversity Research

What?: Diversity at ALL Levels

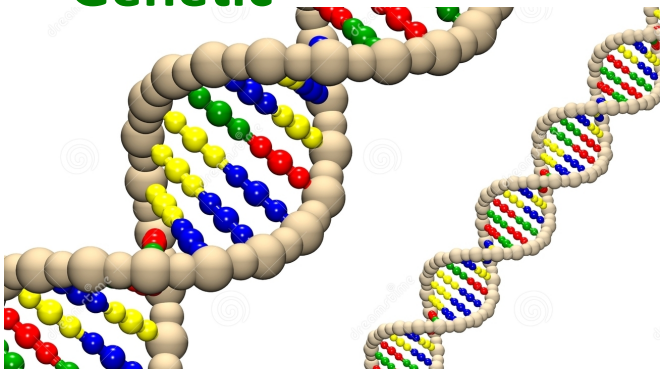
Species

http://blogs.thehindu.com/delhi/wp-content/uploads/2009/02/feb5-featureda.jpg

Ecosystem

http://marinebio.org/oceans/conservation/biodiversity.asp

Genetic



http://www.dreamstime.com/stock-image-dna-illustration-d-background-color-spirals-image30935701

Why Biodiversity??

- Boosts ecosystem productivity
  - Greater number of plants, animals, genetic stock
  - Ensures sustainability of all life forms (maintains interactions)
- Ensures ecosystem recovery
- Maintains ecosystem services
  - A reservoir of resources

- Informs:-
  - Conservation strategies
  - Sustainable development strategies

Threats to Biodiversity

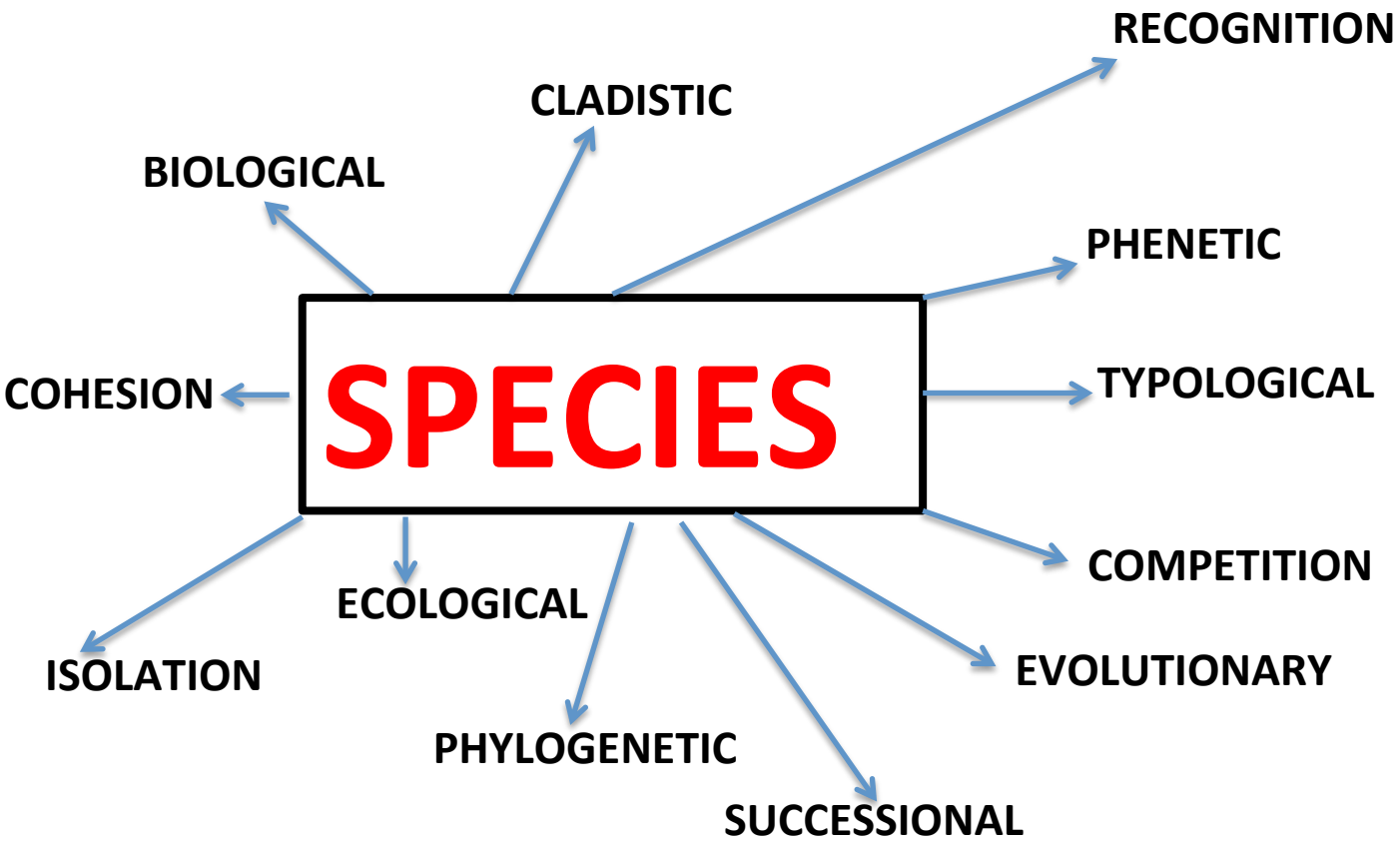
- Climate change: Winning species?
- Natural Resource Over-exploitation
- Planetary Re-engineering
  - Land use change, water diversions, coastal development, fertilizer overuse
- Exotic Species Introductions (both intentional & unintentional)

Factors Used in Biodiversity Assessment

- Number of Species = Species Richness
- Species Evenness; relative species abundance
  - The BEST methods assess both
    - E.g. Simpson's Diversity Index

Are we talking the same language with respect to species?

What Really Are SPECIES?



Approach: Species as Hypotheses

- A **species**: an evolutionarily independent population or group of populations.

Evaluation Criteria

1. Reproductive isolation
2. Morphological distinctiveness
3. Smallest natural/monophyletic group

Criterion 1: Reproductive Isolation

- The **biological species hypothesis**
  - Asserts that populations are ***evolutionarily independent*** if they are reproductively isolated from each other, *i.e.*, they do not interbreed or they fail to produce viable, fertile offspring.
  - Therefore, **no gene flow** occurs between these populations. Pre- or Postzygotic isolating mechanisms established

- **Disadvantages:**
  - The criterion of reproductive isolation cannot be evaluated in fossils or in species that reproduce asexually.
  - It can only be applied to populations that overlap geographically.

TABLE 26.1 **Mechanisms of Reproductive Isolation**

	Process	Example
Prezygotic Isolation		
Temporal	Populations are isolated because they breed at different times.	Bishop pines and Monterey pines release their pollen at different times of the year.
Habitat	Populations are isolated because they breed in different habitats.	Parasites that begin to exploit new host species are isolated from their original population.
Behavioral	Populations do not interbreed because their courtship displays differ.	To attract male fireflies, female fireflies give a species-specific sequence of flashes.
Gametic barrier	Matings fail because eggs and sperm are incompatible.	In sea urchins, a protein called bindin allows sperm to penetrate eggs. Differences in the amino acid sequence of bindin cause matings to fail between closely related populations.
Mechanical	Matings fail because male and female reproductive structures are incompatible.	In alpine skypilots (a flowering plant), the length of the floral tube varies. Bees can pollinate in populations with short tubes, but only hummingbirds can pollinate in populations with long tubes.
Postzygotic Isolation		
Hybrid viability	Hybrid offspring do not develop normally and die as embryos.	When ring-necked doves mate with rock doves, less than 6 percent of eggs hatch.
Hybrid sterility	Hybrid offspring mature but are sterile as adults.	Eastern meadowlarks and western meadowlarks are almost identical morphologically, but hybrid offspring are largely infertile.

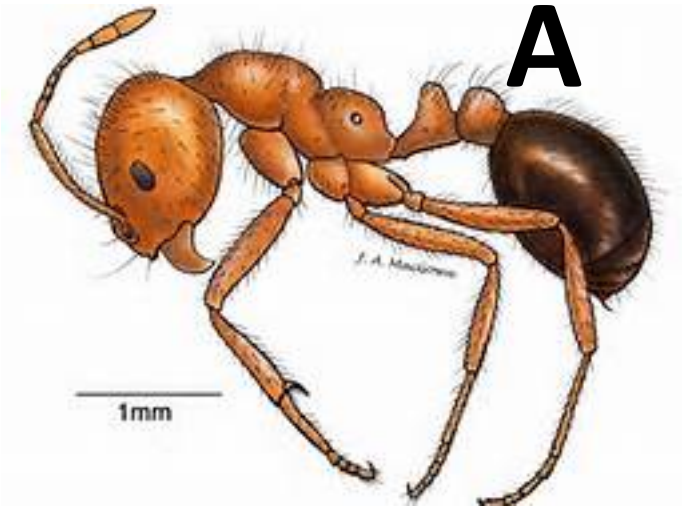
Criterion 2: Morphological Distinctiveness

- Under the **morphospecies concept**, ***evolutionarily independent*** lineages identified by differences in morphological features.

- Assumption: distinguishing features are most likely to arise if populations are independent and **isolated from gene flow**.

- Disadvantages:
  - Cannot distinguish among cryptic species.
  - Features used to distinguish species under this concept are subjective.
  - Juveniles vs. adults; sexual dimorphism

Example: Morphospecies



Species of *Solenopsis*

A. *S. invicta*
B. *S. molesta*
C. *S. xyloni*

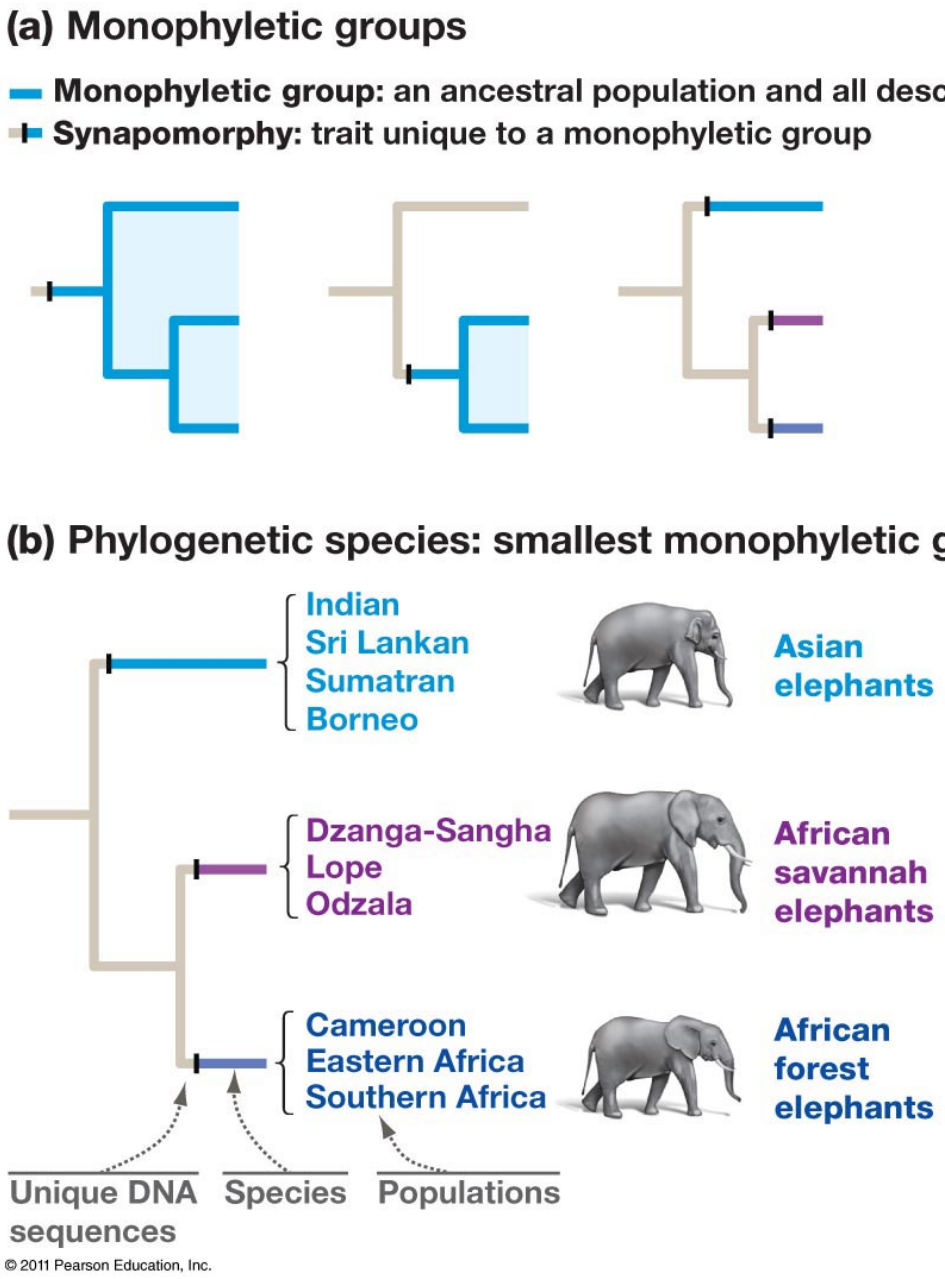
Criterion 3: Phylogenetic Distinctiveness

- The **phylogenetic species concept,** requires the reconstruction of the evolutionary history of populations.

- On phylogenetic trees, an ancestral population plus all of its descendants is called a **monophyletic group, lineage** or **clade**.
  - Identified by **synapomorphies**
    - Homologous traits inherited from a common ancestor and unique to certain populations or lineages.

- In this case, a **species** is defined as the **smallest monophyletic group** on the tree of life.

Example: Phylogenetic species



Phylogenetic Distinctiveness

- Disadvantages:
  - Phylogenies are currently available for only a tiny proportion of populations.
  - Some argue that it would probably lead to recognition of many more species than either of the other species concepts.

- In practice, researchers use all three (multiple) species concepts to identify evolutionarily independent populations in nature.
  - Why apply different criteria for evaluating species?
  - Aren't all species the same?
  - Aren't they all products of evolution by natural selection?

- Species = population(s) that appear to be evolutionary independent (pattern).
- Speciation; isolation and divergence (process)
  - Divergence mechanisms are similar
  - Isolating mechanisms not necessarily similar (process).
- Development of a unifying concept for all species must consider both patterns and processes.
- Thus, because of the diverse array of isolating mechanisms and their impacts on 'SPECIESNESS', a single criterion may not be practical.

Estimated # Species (IUCN 2007)

Group	# of Species	Group	# of Species
Amphibians	6,199	Crustaceans	40,000
Birds	9,956	Corals	2,175
Fish	30,000	Arachnids +	130,200
Mammals	5,416	Plants	297,326
Reptiles	8,240	Lichens	10,000
Insects	950,000	Fungi	16,000
Molluscs	81,000	Brown Algae	2,849

Total = 1,589,361; Predicted – 2 to 50 million

Estimated # Species (IUCN 2010)

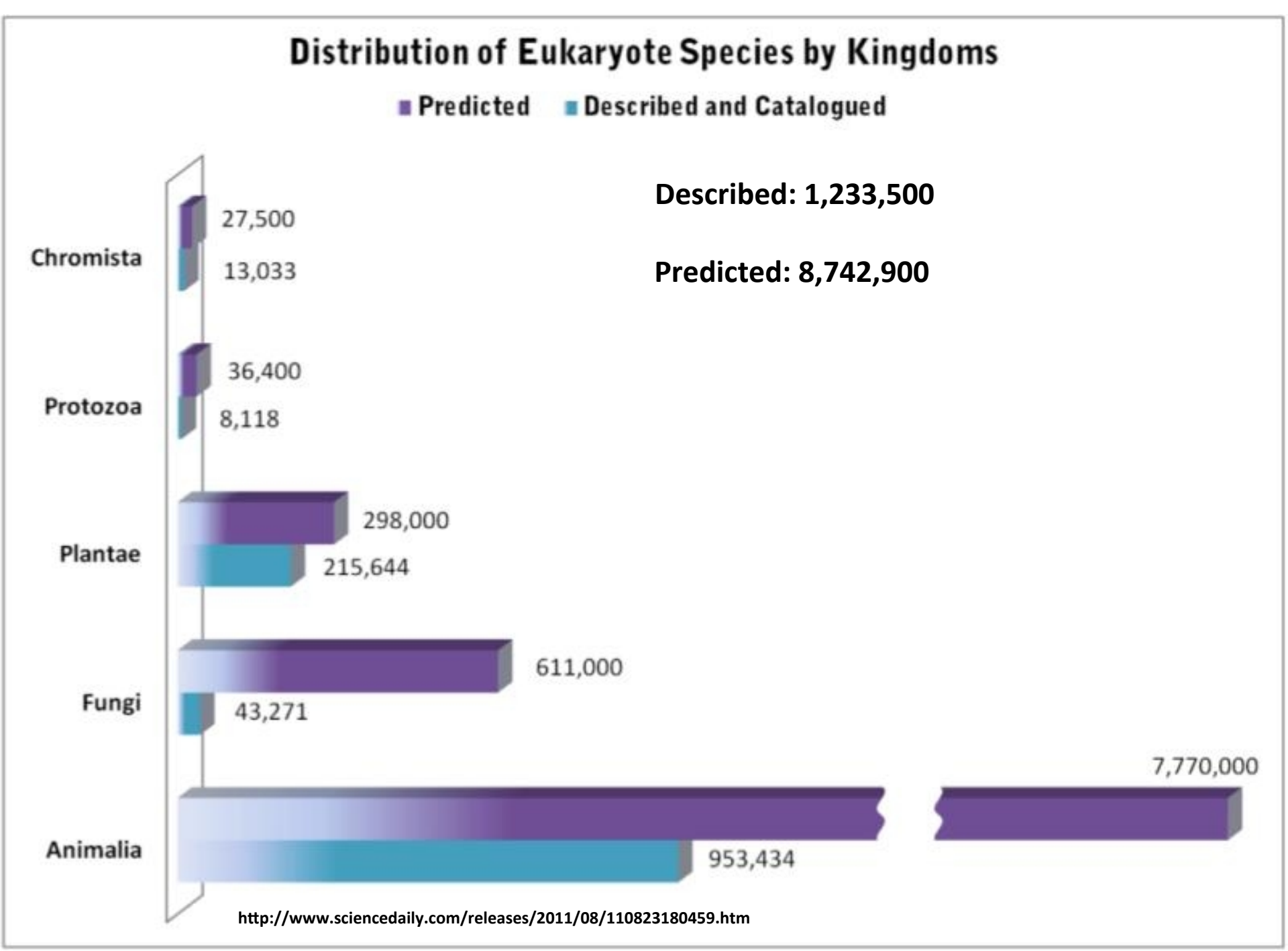
Group	# of Species	Group	# of Species
Amphibians	6,433	Crustaceans	47,000
Birds	9,998	Corals	2,175
Fish	31,300	Arachnids	102,248
Mammals	5,490	Plants	321,212
Reptiles	9,084	Lichens	17,000
Insects	1,000,000	Fungi	31,496
Molluscs	85,000	Brown Algae	3,067
Other Inverts	68,827		

Total = 1,740,330; Predicted – None Provided

Estimated # Species (Chapman 2009)

Group	# of Species	Group	# of Species
Amphibians	15,000	Crustaceans	150,000
Birds	10,000	Echinoderms	14,000
Fish	40,000	Arachnids	600,000
Mammals	5,500	Plants	390,800
Reptiles	10,000	Lichens	Not provided
Insects	5,000,000	Fungi	Not provided
Molluscs	200,000	Brown Algae	Not provided
Other Inverts	791,830		

Total = 7,227,130; Predicted – 11.3 million


Distribution of Eukaryote Species by Kingdoms
Predicted
Described and Catalogued
Described: 1,233,500
Predicted: 8,742,900
Chromista
27,500
13,033
Protozoa
36,400
8,118
Plantae
298,000
215,644
Fungi
611,000
43,271
Animalia
7,770,000
953,434
http://www.sciencedaily.com/releases/2011/08/110823180459.htm

Evidence Across Estimates

- Most likely all species identified
  - Mammals
  - Birds
  - Coniferous plants
- Substantial increases expected for most other groups
- Missing information
  - Unicellular eukaryotes
  - Bacteria & Archaea
- No consensus on predicted number; just much more than those described

- “Although such rough approximations of the diversity of life are not too difficult to make, the exact number of species is beyond reach because—incredibly—the majority have yet to be discovered and specimens placed in museums. Furthermore, among those already classified no more than a dozen have been studied as well as the honeybee.” Wilson, Edward O. (1984-10-01). Biophilia (pp. 20-21). Harvard University Press

STATUS ASSESSMENT

- Collections in Support of Biological Research (CSBR)
- Advanced Digitization of Biological Collections (ADBC)
  - Security and improvement of NH collections
  - Digitized specimens and related data
  - Imaged specimens
  - Development, improvement and application of curatorial practices
  - Improved accessibility to specimens and related data

STATUS ASSESSMENT Cont'd

- **Result:** Over 8,000,000 specimen Records, and increasing daily

- Goal = Stimulate Innovative Research
- Integrated across taxa
- Interdisciplinary
- Integrated research and education
- What gets done is dependent on our creativity and imagination

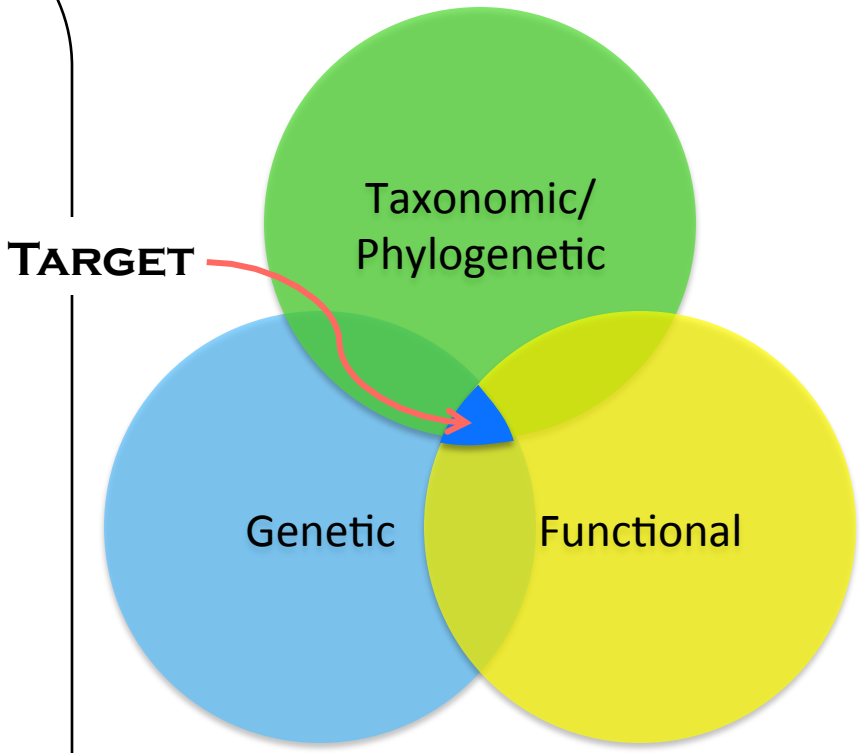
Dimensions of Biodiversity

A 10-year campaign to characterize the dimensions of biodiversity on Earth

Purpose:

- Integrative approaches
- Innovative concepts
- Rapid advances

with an initial focus on areas where three key dimensions overlap to contribute to the well-being of humans and societies, the generation of new wealth, and the functioning of ecological systems



Genealogy of Life (GoLife)

Objectives of *GoLife*

- A single, cohesive, automated, updatable, dynamic, continually evolving ToL providing the phylogenetic infrastructure for all biodiversity. Queryable.

- Powerful visualization tools enabling identification of strongly supported vs. weakly supported areas of the tree; 'dark areas' illustrating need for more work; navigation tools to traverse every branch of the tree and processes within the lineages.

- All associated metadata (voucher specimens, range maps, images, stratigraphic record, etc) tied to a universal ToL.

- Tips of trees ("species") tied to digitized voucher specimens and all their associated metadata.

“So long as a branch of science offers an abundance of problems, it will stay alive; a lack of problems foreshadows extinction or the cessation of independent development.”

Wilson, Edward O. (1984-10-01). Biophilia (p. 59). Harvard University Press

"Merely the attempt to solve the biodiversity crisis offers great benefits never before enjoyed, for to save species is to study them closely, and to learn them well is to exploit their characteristics in novel ways"

Wilson, Edward O. (1992). The Diversity of Life (p. 306). W. W. Norton & Company


Thank You