

Ontology of Evolution: Species and Units of Selection

"It is really laughable to see what different ideas are prominent in various naturalists' minds, when they speak of 'species'; in some, resemblance is everything and descent of little weight — in some, resemblance seems to go for nothing, and Creation the reigning idea — in some, sterility an unfailing test, with others it is not worth a farthing. It all comes, I believe, from trying to define the indefinable" (Darwin, December 24, 1856)

Why does it Matter How Species are Characterized?

- Scientifically?
 - Understanding evolution
 - Using species as model systems
- Morally?
 - Is X a human being (in the moral sense)?
 - What obligations do we have to certain organisms?
- Public Policy?
 - Should we protect it?

Size of the Problem

Estimated number of species in different orders

- 5–10 million bacteria
- 1.6 million eukaryote species
 - 297,326 plants
 - 28,849 fungi & other non-animals
 - 1,250,000 animals
 - 1,203,375 invertebrates
 - 59,811 vertebrates:
 - 29,300 fish
 - 6,199 amphibians
 - 8,240 reptiles
 - 9,956 birds
 - 5,416 mammals

Natural Kinds



- A kind (or a set) is defined in terms of essential properties
 - All and only entities with the essential properties are instances of the kind
- Essential properties explain the key characteristics of the kind
- From knowing the essence, we can predict the properties associated with the kind

Clicker Question

Suppose that a trait were found in all members of a species. Would that establish it as the essence of the species?

Yes, that would make it the essence of the species

No, since observers might not be able to readily identify whether an individual possessed the trait

No, since that trait might also be possessed by individuals in other species

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Clicker Question

The alternative to species being natural kinds/classes with essences that is discussed in the reading is

That species do not exist, only varieties do

That species are individuals that are spatially, temporally restricted

That species are useful fictions created by scientists to make sense of our world

That although species do have essences, they are not really natural kinds

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Discussion Question

Do you have an essence?

Yes, there is a trait that I, and only I have, and I can tell you what it is

Yes, there is a trait that I, and only I, have, but I cannot tell you what it is. I just know there has to be something distinctively me.

No. I can change my traits by taking appropriate actions

No. I am a continuing entity from birth to death, but my traits can change over time

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Species as Natural Kinds (Sets)?

- Are any traits necessary or sufficient to being a member of a species
 - Would a mutant lacking the traits be excluded from the species?
 - Would a mutant of another species that acquired the trait become a member of the species?
 - Are there any sharp boundaries between members and non-members of a species?



Species as Individuals



- David Hull and Michael Ghiselin advanced an alternative to the traditional view that species are kinds or sets
 - Where sets are specified in terms of conditions of set membership (i.e., essential properties)
- They argued that evolutionary theory requires treating species as historical individuals—they are born and they go extinct
 - In this respect, they are individuals—spatially, temporally extended entities
 - Species don't have members but parts
 - You and I are parts of the species homo sapiens, not members of it

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Clicker Question

On the view that species are individuals, which of the following is true of the Dodo Bird (now extinct)

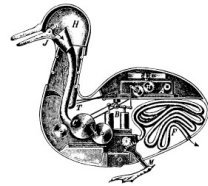


- A new Dodo bird could evolve in the future
- Some Dodo birds might have had different appearances than others
- There are scientific laws about Dodo birds
- Dodo birds could have evolved independently in different places

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Surprising Consequences of Species as Individuals

- Individual species cannot be the subject of scientific laws
- If it walks like a duck, quacks like a duck, . . . , but was not born of a duck, it is not a duck
 - And if it is born of a duck, it is a duck even if it doesn't look like a duck, quack like a duck, . . .
- There cannot be ducks, or people, anywhere else in the universe
 - Even if they look just like us, and speak English



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Individualism and Human Nature

- Many people are deeply concerned to figure out what human nature consists in
 - Language?
 - Tool use?
 - Sociality?
- But, if species are individuals, there is no human nature
 - There is just a lineage of organisms, some of which may differ dramatically from others

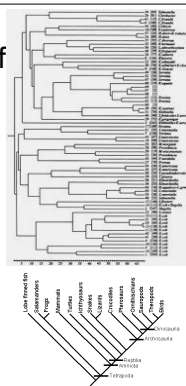
Responses to Species as Individuals

- Some have found the idea that a species is nothing more than a lineage impossible to accept
 - Devitt argues there must be an essence (intrinsic feature) that determines why the members of a species exhibit the traits they do
- Boyd's Homeostatic Property Clusters: There are a cluster of processes that promote stability (homeostasis) within a species
 - Gene flow
 - Stabilizing pressure
 - Developmental homeostasis
- Pluralism: different species concepts for different purposes
 - Kitcher argues that for proximate explanations (physiology, molecular biology) species are defined in terms of their traits

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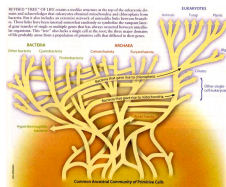
Some Candidate Accounts of Species

- Phrenetic species concept: species are groups defined in terms of overall similarity
- Phylogenetic species concept: species are lineages of ancestral/descendant populations between speciation events
 - Hennig: speciation always involves splitting of existing species (which then cease to exist)
- Biological species concept: species are populations that are reproductively isolated
 - Mayr: isolation via "biological properties of individuals which prevent the interbreeding [fusion] of populations"



The Prokaryote Challenge

- Since Weismann in the late 19th century, the dominant view has been that genetic material is transferred only vertically from parents to offspring
- In bacteria, however, lateral gene transfer—transfer of genes from one organism to another is coming to be recognized as quite common
- It appears likely that eukaryotic cells (cells with internal organelles such as a nucleus and mitochondria) resulted from the combining of two prokaryotes (one becoming the mitochondrion or the chloroplast)
- This raises serious problems for the tree of life and phylogenetic constructions of species



Different but Related Issue: At What Level Does Natural Selection Occur?

- Darwin presented his account in terms of organisms—they were either favored or harmed in reproduction by how adaptive they were to current conditions
- Population genetics made genes the focus—selection favored or counted against genes being passed on
- Are there other levels of organization that figure in Natural Selection?
 - In *The Descent of Man* Darwin focused on altruism and on how the sacrifice of individuals helped their group at their own expense

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At What Level Does Natural Selection Occur?

- Wynn-Edwards proposed that animals restricted their own reproduction to benefit the group
- Williams (1966) argued against group selection and for all selection occurring at the level of genes
 - There is no mechanism by which those who sacrificed for the group would leave more offspring
- This set up the question: Are there any units larger (at a higher level) than genes that need to be considered?
 - Linkage groups?
 - Chromosomes?
 - Genomes?
 - Organisms?
 - Groups?
 - Species?

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The Gene as the Unit of Evolution



- In *The Selfish Gene* Richard Dawkins:
 - Replicators: That which is directly copied
 - Vehicle: That which houses replicators and serves to protect and propagate them—organisms
 - Vehicles are what interact with the environment
 - But the gene is the fundamental unit of evolution
- David Hull
 - Replicator: “an entity that passes on its structure directly in replication” (Hull 1980, p.318)
 - Interactor: The entity which interacts with the environment such that replication is differential
 - Natural selection: “a process in which the differential extinction and proliferation of interactors cause the differential perpetuation of the replicators that produced them” (Hull 1980, p. 318)

House Mouse and t-allele



- Evolutionary processes operate on interactors at three levels
 - Favored at the level of sperm: 80% of the sperm from heterozygotes carry the t-allele (normal = 50%)
 - Selected against at the organism level: Males homozygotic for the t-allele are sterile
 - Selected against at the group level as groups with all sterile males go extinct
- At different levels selection seems to be working in opposite directions but all the effects accrue to the same allele

What Replicates?

- Organisms do not—their traits are broken up in reproduction
- Chromosomes do not—the genes on them can recombine
- Only genes! They are the “indivisible fragments”
 - Dawkins: Analyze evolution solely at the genic level
 - It is a mistake to focus on organisms (interactors) since they are not what benefit from selection
 - An organism is just a gene’s way of making copies of themselves
 - All benefit accrues to the genes (e.g., the t-allele)
- But even genes are not perfectly replicated
 - And their function is modified by epigenetic processes
- Should we rethink the conclusions above?

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Clicker Question

What would it take to show that selection operates on a higher level than genes

That genes are not the units that interact with selection forces in the environment

That genes are not replicators

That genes are located on chromosomes

That things at a higher level of organization than genes (organisms, groups) replicate and benefit from Natural Selection

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Discussion Question

Being a member of a group (e.g., political parties, monogamous relationships) often restricts an individual's freedom. Why would individuals do this?

They also gain from the fact that the group can accomplish more than solo individuals

They believe in the goals promoted by the group

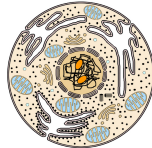
They feel coerced into being a member of the group

They don't realize that they are missing out on benefits they would have had if they had stayed independent

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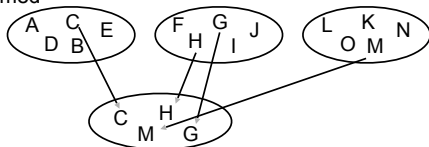
Higher Level Organizations in Nature

- Bacterial swarms
 - Individual bacteria no longer "free" to go off on their own
- Eukaryotic cells: formed from the incorporation of one bacteria into another (or into an Archaea)
 - Bacteria provided mitochondria and chloroplasts
 - These organelles lost their independence when they became components of larger cells
- Multi-cellular organisms
 - Division of labor as different cells specialize in different functions (blood cells in carrying oxygen, neurons in transmitting action potentials)
 - But none is able to live independently
 - Cancer: individual cells breaking free of the yoke of being part of a overall organism that restricts its reproductive potential
- Organized groups of organisms in which tasks are distributed



Modeling Group Selection

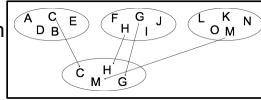
- A major argument against selection operating on groups was that mathematical models suggested it was impotent to produce evolutionary change
- These models all approached the problem by starting with several groups of individuals and selectively chose from them those that would contribute to the pool from which new groups are formed



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Discussion Question

In what way did this approach encounter a problem that Darwin also confronted?



It involves blending inheritance

It makes evolution work too slowly given the age of the earth

It relies totally on selection and fails to take advantage of inheritance of acquired characteristics

It assumes much more variability than found among actual groups

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Michael Wade and Tribolium

- Performed an experiment with flour beetles
 - Offspring groups originate within a single group—ABSOLUTELY REQUIRED
 - Within groups, the most fecund leave the most offspring
 - Groups with low fecundity—Wade simply eliminated those with the most fecundity
 - He found that overall fecundity declined
- Why?
 - Although within a given group, fecundity was more likely to rise, that was swamped by the promotion of groups with least fecundity



Simpson's Paradox

- Partitioning a population into two parts can result in a reversal in the direction of relation between two variables
 - The death rate from tuberculosis for African Americans was **lower** in Richmond than in New York.
 - The death rate from tuberculosis for Caucasians was **lower** in Richmond than in New York.
 - The death rate for the total combined population of African Americans and Caucasians from tuberculosis was **higher** in Richmond than in New York.
- While not a strict analog of group selection, Simpson's paradox provides an intuitive understanding of how something can be favored in sub-populations, but selected against in the whole population (or vice versa)

Simpson's Paradox

Population	New York	Richmond
White	4,675,174	80,895
Black	91,709	46,733
Combined	4,766,883	127,628
Deaths	New York	Richmond
White	8,365	131
Black	513	155
Combined	8,878	286
Mortality rate	New York	Richmond
White	.179%	.162%
Black	.560%	.332%
Combined	.186%	.224%

Group Selection for Altruism

Selfish Group	Selfish Individuals	Altruistic Individuals
Before	40	5
After	20	0
Altruistic Group	Selfish Individuals	Altruistic Individuals
Before	5	40
After	8	40
Combined	Selfish Individuals	Altruistic Individuals
Before	45	45
After	28	40
