The Human Factor in Evolution

Nearly 6,000,000,000 humans currently inhabit the earth.

Massive human population growth has been supported by agricultural, industrial, and technological developments, which have forever altered the course of earth's evolutionary history.

Homo sapiens has been the first species to impose its own subjective assessments of the "quality" of members of other species, redirecting selection for its own purposes.

→ Artificial selection

Example: Average egg production rose from 20 eggs/chicken to over 100 eggs/chicken between 1933 and 1965.

Example: Mean corn cob length has increased from about 1 cm (in teosinte) to more than 12 cm over a period of 7000 years.

Humans have recently caused directed mutations (via genetic engineering) in an attempt to hasten the evolutionary response.

Example: Genes for human growth hormone injected into mice zygotes resulted in giant mice that grew to twice the normal adult size. Giant mice then passed on the gene to their offspring.

In this lecture, we will examine two aspects of how humans have altered the tempo and mode of evolutionary change:

- human-induced mass extinction
- cultural evolution

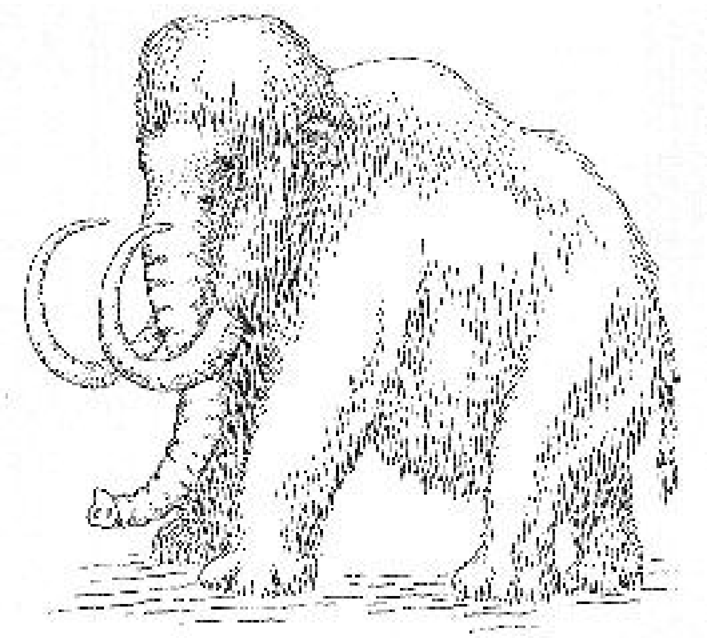
The Next Mass Extinction

From the early evolution and spread of *Homo sapiens*, our species has been associated with the disappearance of species.

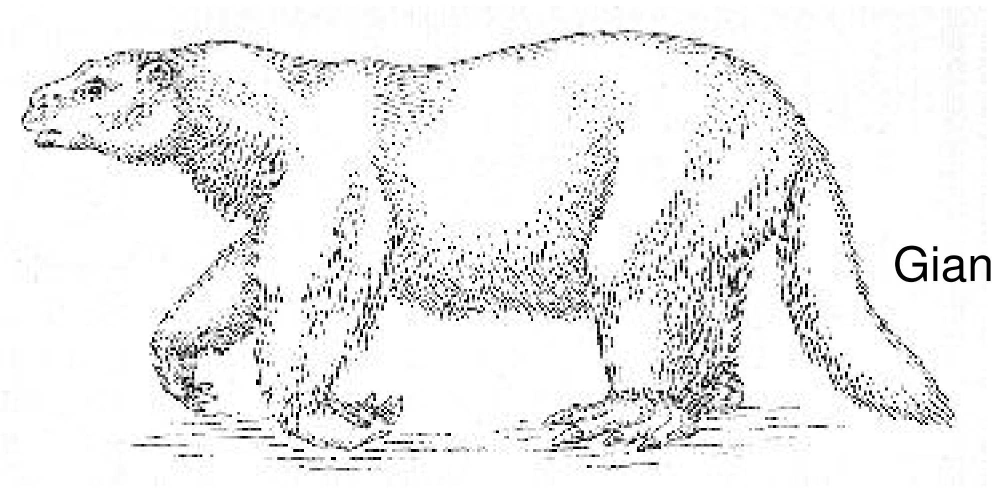
During the last 10,000 to 100,000 years, a number of large, terrestrial mammals have gone extinct.

In North America, 70% (38/54) of the large mammal species went extinct, including:

- an endemic camel
- an endemic musk ox
- the mastodon
- the wooly mammoth
- the saber-toothed cat
- a large beaver (~ 150 kg!!)
- the American cheetah
- two species of tapir
- the giant ground sloth



Wooly Mammoth



Giant Sloth

Two possible explanations have been advanced for these extinctions: climate changes over the last 100,000 years and/or hunting by early humans.

What is unusual about these extinction events is that they were so selective: small-bodied mammals, marine invertebrates, plants, insects, and birds were unaffected.

Such selectivity is consistent with the idea that large mammals went extinct from hunting, but this is still hotly debated.

A clearer example of pre-historic human-induced extinctions comes from island species of birds.

Steadman (1995) estimated that 2000 species of birds have gone extinct on Pacific islands following human colonization.

The evidence presented by Steadman and colleagues includes:

- Loss of 60 species on the Hawaiian islands following the arrival of humans 1500 ybp.
- Loss of 44 species (including moas) in New Zealand following human colonization
- Loss of 21/27 species of birds on ’Eua (Tonga) following human arrival
- Loss of 20 taxa on the Galapagos islands in the last two hundred years (compared to three in the preceding 4000-8000 years)

What caused these losses?

Evidence in early fire pits and middens suggests that humans directly consumed many of these bird species.

Humans brought to these islands additional threats to island species: mammalian predators, (especially rats and dogs) and diseases (e.g. birdpox introduced into Hawaii in the 1890's).

Finally, humans altered island habitats, via slash-and-burn agriculture, deforestation, and irrigation.

➡ Extinctions have been a hallmark of human history.

The Crisis Expands

Sadly, many species have gone extinct during recent human history and many more remain greatly threatened.

Current extinction rates are estimated to be 100-1000 times above background levels (estimates from such eminent ecologists as Stuart Pimm, Paul Ehrlich, and E. O. Wilson).

	# species certified extinct since 1600
Molluscs	191
Insects	61
Vertebrates	229
Plants	584

[From Smith et al. (1993); estimates are underestimates for poorly studied groups.]

Gone forever are the dodo bird, the passenger pigeon, the great auk, the Carolina parakeet, the quagga, Stellar's sea cow, Schomburgk's deer, Antarctic wolf, the Tasmanian wolf...

But while these numbers are large, they do not (YET!) approach the levels of the "big five" mass extinction events.

The *known* losses over the last 400 years represent around 1% or less of extant species (compared to the 50%-90% losses experienced during the "big five").

But extend these losses for a few thousand years and the numbers will become comparable.

And the situation will worsen.

Increased demands on resources:

Human population size continues to grow and is expected to double within the next forty years.

As countries develop, human demand on land and fossil fuels increases faster than population growth.

Resource	US consumption (per capita)	Indian consumption (per capita)
Petroleum	2.53 metric tons	0.057 metric tons
Natural gas	81.3 metric tons	0.47 metric tons

Reduced resource base:

By 1989, tropical forests had declined to about 50% of their pre-human levels, declining at a further rate of 1.8% per year (and growing).

> "In 1989 the surviving rain forests occupied an area about that of the contiguous forty-eight states of the United States, and they were being reduced by an amount equivalent to the size of Florida each year."
>
> --E. O. Wilson (1992) *The Diversity of Life*

Land area of forests in Costa Rica

These tropical rain forests are thought to contain at least half of the world’s species, 10 to 25 percent of which are expected to go extinct within the next 30 years.

Deterioration of remaining habitats:

In addition to deforestation, the physical environment of all living species has been adversely affected by

- air pollution
- water pollution
- loss of top-soil
- acid rain
- depletion of ozone layer
- rise in global temperatures

Similarly, the biotic environment has been adversely affected by the introduction of non-native competitors, predators, and diseases.

➡ As many as 150-200 species may be going extinct every day (estimate from Rio+5 group sponsored by the Earth Council).

As with each mass extinction, the process of evolution will forever-more be shaped by those fortunate species that survive decimation.

Unlike the former mass extinctions, however, there is one major characteristic that defines who will survive and who will perish: ability to co-exist and thrive alongside human populations.

Cockroaches, pigeons, starlings, rats, dandelions, and similar species are the likely winners in this, the sixth, mass extinction.

Cultural Evolution

Evolutionary change in a trait occurs whenever:

- individuals vary in some trait (VARIANCE)
- individuals with some trait values are more likely to live and/or reproduce than other individuals (SELECTION)
- trait values may be passed from individual to individual (HERITABILITY)

Although we have focused on the evolution of traits that are passed from parents to offspring via genetic inheritance, evolution can also act on traits that are "inherited" culturally.

Traditions, ideas, phrases, fads, or skills can be passed from individual to individual, not through genes but through communication.

Besides vertical transmission (= from parents to offspring), cultural transmission can occur horizontally (= among peers) or obliquely (= from any member of an older generation to any member of a younger generation).

Example: Cavalli-Sforza et al (1981) collected information about the cultural inheritance of a variety of traits.

Salt consumption

Father x Mother	**"High" offspring**
"High x High"	60%
"High x Low"	36%
"Low x High"	65%
"Low x Low"	26%

(Example of maternal transmission.)

Political Interest

Father x Mother	"High" offspring
"High x High"	72%
"High x Low"	44%
"Low x High"	40%
"Low x Low"	25%

(Example of biparental transmission.)

Richard Dawkins (1976) coined the term "meme" to refer to the unit of cultural evolution (analogous to gene).

Examples of memes: roller-blades [inventions], "hey dude" [phrases], lattes [great ideas].

Like genes, memes can "mutate" during transmission.

Like mutant alleles, mutant memes can be selectively favored (high transmission) or disfavored (low transmission).

For instance, Imo, a two-year old Japanese macaque was the first to learn to wash sand off of sweet potatoes by throwing them in water. This behavioral "mutation" then rapidly spread, via learning, to other members of her troop.

Cultural and genetic evolution are not mutually exclusive, as demonstrated by the example of lactose tolerance.

Adult mammals are generally lactose intolerant.

With the increase in dairy farming over 6000 years, however, lactose tolerance has increased from about 20% (among populations without dairy traditions) to 90%.

The change in lactose absorption is due mainly to genetic differences, but the change in farming practises that led to selection for absorption was cultural.

Cultural evolution can be rapid and can change the way we view the world.

A final thought:

What sorts of "memes" may help slow the rate of extinctions caused by humankind?

What factors may favor the spread of such "memes"?

SOURCES OF INFORMATION AND FIGURES:

- Futuyma (1998) Evolutionary Biology. Sinauer Associates, MA.
- Freeman and Herron (1998) Evolutionary Analysis. Prentice Hall, NJ.
- Cavalli-Sforza and Feldman (1981) Cultural Transmission and Evolution.
- Feldman and Laland (1981) Gene-cultural coevolutionary theory. TREE 11:453-457.