EVOLUTIONARY BIOLOGY
150 YEARS OF PROGRESS

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DARWIN’S THEORIES

1. Descent with modification: All species have descended, by branching of lineages, from common ancestors, with modification.

2. Modification is a two-step process: (A) Inherited variation arises (by unknown causes); (B) Rare variants increase in frequency gradually replacing the formerly prevalent form of the species. This evolutionary change is a modification of the POPULATION. A new variant is not generally a new species.

3. The cause of this gradual replacement is a difference reproductive rate or survival: NATURAL SELECTION.

4. Advantageous new variants differ only slightly from the parental form; great evolutionary changes result from sequential accumulation of slight differences.

5. New variants arise independently of their adaptive value or of the organism’s “needs.” [But Darwin also allowed for inheritance of environmental modifications.]
MUTATIONS

Gregor Mendel

First Generation
- Yellow (yy)
- Green (YY)

Second Generation
- Green (Yy)
- Green (YY)
- Green (Yy)
- Yellow (yy)

Mary S. Gibbs (GNN)
THEMES OF THE EVOLUTIONARY SYNTHESIS

Theory of population genetics
   Importance of natural selection

Abundant genetic variation
   (but argument about causes)

Coadaptation of genes
   (vs. “beanbag genetics”)

Species are reproductively isolated populations that arise by
   allopatric divergence due to ecological selection, founder effect

Population genetics and ecology explain macroevolution
EVOLUTIONARY BIOLOGY IN 1959

Watson & Crick only 6 years before
No DNA sequences; code unknown;
No molecular polymorphisms or markers

Primitive computers
No phylogenetic methods

Few field studies of natural selection
Little convincing evidence of genetic drift
PROGRESS IN EVOLUTIONARY BIOLOGY

Molecular biology: understanding and methods

Technical advances: computation and informatics

Theoretical and conceptual advances

Synthesis and extension
A SCIENCE OF ADAPTATION
Model of resource allocation

Evolution of Life Histories

Allocation to reproduction higher in annual than perennial grasses
Cooperation explained by kin selection (in part)

Conflict
Genetic conflict: cytoplasmic vs. nuclear genes affecting male sterility
UNDERSTANDING CONFlict
SEXUAL SELECTION

Peacock

Insect

The image shows a peacock and an insect, which are examples of sexual selection in animals.
SEXUAL SELECTION
EVOLUTIONARY GENETICS
DNA sequence variants

Allozymes
Comparisons of DNA sequences between species show that evolution is most rapid where changes have no effect on function.

Support for the NEUTRAL THEORY, that most evolution at DNA level is by random genetic drift, not natural selection.
Dating evolutionary events
Most evolution of phenotypic characteristics is adaptive, due to natural selection.

Hundreds of species of insects have evolved resistance to insecticides.

Evolution of new migratory route in Blackcap
Melanocortin-1 receptor mutations determine melanism polymorphism in diverse vertebrates.

*Perognathus intermedius* pocket mouse

*Peromyscus polionotus* beach mouse

*Chen caerulescens* snow goose

*Stercorarius parasiticus* parasitic jaeger (Arctic skua)
SELECTIVE SWEEP: Fixation of advantageous mutation makes population uniform at closely linked DNA sites. Preexisting variation is “swept away”. New variation builds up over time.
Selective sweeps detected in human populations, with age detected by level of variation at nearby DNA sites. Pattern suggests increased evolution by natural selection in last 40,000 years.
PHYLOGENY
AND EVOLUTIONARY HISTORY
PHYLOGENY OF APES,
BASED ON SEQUENCE OF HEMOGLOBIN PSEUDOGENE

M. Goodman et al. 1989, et seq.
Phylogenetic sister-group tests for effects of characters on diversification rate

Example:

Does sexual selection enhance diversification (speciation)?
EVOLUTIONARY ORIGIN OF THE HUMAN GENES IN THE GLOBIN GENE FAMILY
Human mitochondrial DNA sequences support recent spread from Africa throughout world, replacing archaic Homo in Eurasia.

Human populations outside Africa estimated to have spread over the last 50,000 years.
MANY PHENOMENA ARE STILL POORLY UNDERSTOOD

How do species coevolve?

How does adaptation to very new environments or resources occur?

How do phenotypes evolve?

Does standing genetic variation provide adaptation?
Does the rate of advantageous mutation limit adaptation?
How can rapid evolution be reconciled with stasis, niche conservatism, and extinction?
The paradox of stasis and slow evolution... …even though adaptation often is rapid, based on standing genetic variation.
PROGRESS IN EVOLUTIONARY BIOLOGY

Theory and modelling

Building on all biological disciplines

Technical advances

An Enduring Synthesis of the life sciences
EVOLUTIONARY
DEVELOPMENTAL BIOLOGY
Hoxc6 gene expression marks development of thoracic vertebrae
## The Genetic Code

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*EVOLUTION, Figure 8.2 © 2005 Sinauer Associates, Inc.*
PHYLOGENY OF THE APES,

BASED ON HEMOGLOBIN PSEUDOGENE

M. Goodman et al. 1989, et seq.
Environment-induced heterophylly in *Ranunculus flammula*

Certain terrestrial and aquatic populations cannot be induced to form alternative leaf phenotype.

S.A. Cook and M.P. Johnson 1968, Evolution 22:496-516
Phylogeny of Apes

Gibbon (Asia)
Orangutan (Asia)
Gorilla (Africa)
Human (Africa)
Bonobo (Africa)
Chimpanzee (Africa)
The paradox of stasis and phylogenetic niche conservatism
Sexually Dimorphic

Sexually Monomorphic
EVOLUTION OF GENETIC SYSTEMS

Evolution of sex chromosomes

Model of evolution of proto-sex chromosomes by fixation of recessive male-sterility mutation ($M^F >> M^S$), then a dominant female-sterility mutation ($F^f >> F^S$).

Mapping Quantitative Trait Loci

Chromosomes 3 of flies selected for:

Sternopleural bristles

QTL for sternopleural bristles

High Low

Abdominal bristles

High Low
COALESCEENCE

Gene copies in current population are descended from a single ancestral copy, other gene lineages having been lost by genetic drift.
The Evolution of Life
Its Origin, History and Future

Cold Spring Harbor Symposia on Quantitative Biology

Volume XXIV

Genetics and Twentieth Century Darwinism

The Biological Laboratory
Cold Spring Harbor, L. I., New York
1939