1 ☐ evolution

2 ☐ Darwin

- On November 24, 1859, Charles Darwin published *On the Origin of Species by Means of Natural Selection*.
- Darwin made two points in *The Origin of Species*:
  - Today's organisms descended from ancestral species.
  - **Natural selection** provided a mechanism for evolutionary change in populations.

3 ☐ Carolus Linnaeus

- In the 1700's, the dominant philosophy, **natural theology**, was dedicated toward studying the adaptations of organisms as evidence that the Creator had designed each species for a purpose.
- At this time, Carolus Linnaeus, a Swedish botanist, developed **taxonomy**, a system for naming species and grouping species into a hierarchy of increasingly complex categories.

4 ☐

- Darwin's views were influenced by **fossils**, the relics or impressions of organisms from the past, mineralized in **sedimentary rocks**.
  - Sedimentary rocks form when mud and sand settle to the bottom of seas, lakes, and marshes.
  - New layers of sediment cover older ones, creating layers of rock called strata.
  - Fossils within layers show that a succession of organisms have populated Earth throughout time.

5 ☐

- **Paleontology**, the study of fossils, was developed by Georges Cuvier, a French anatomist. Cuvier documented the succession of fossil species in the Paris Basin.
  - Cuvier recognized that extinction had been a common occurrence in the history of life.
  - Instead of evolution, Cuvier advocated **catastrophism**, that boundaries between strata were due to local flood or drought that destroyed the species then present.
  - Later, this area would be repopulated by species immigrating from other unaffected areas.

6 ☐ **Theories of geological gradualism helped clear the path for evolutionary biologists**

- In contrast to Cuvier's catastrophism, James Hutton, a Scottish geologist, proposed that the diversity of land forms (e.g., canyons) could be explained by mechanisms *currently* operating.

- Hutton proposed a theory of **gradualism**, that profound change results from slow, continuous processes.
- Later, Charles Lyell, proposed a theory of **uniformitarianism**, that geological processes had not changed throughout Earth's history.

7 ## Lamarck's mechanism of evolution

- Central to his hypothesis were the concepts of use and disuse of parts and of inheritance of acquired characteristics.
  - The former proposed that body parts used extensively to cope with the environment became larger and stronger, while those not used deteriorated.
  - The latter proposed that modifications acquired during the life of an organism could be passed to offspring.
  - A classic example of these is the long neck of the giraffe.

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- Lamarck's theory was a visionary attempt to explain both the fossil record and the current diversity of life through its recognition of the great age of Earth and adaptation of organisms to the environment.

9 ## Field research and Darwin

- Grad from seminary 1831 (naturalists and biologists were largely clergy)
- After graduation Darwin was recommended to be the conversation companion to Captain Robert FitzRoy, preparing the survey ship *Beagle* for a voyage around the world.
- FitzRoy chose Darwin because of his education, his similar social class, and similar age as the captain.

10 ## **Field research helped Darwin frame his view of life**

- The main mission of the five-year voyage of the *Beagle* was to chart poorly known stretches of the South American coastline.

11 ## Darwin's OBSERVATIONS

- Organisms from temperate regions of South America were more similar to those from the tropics of South America than to those from temperate regions of Europe.
- Further, South American fossils more closely resembled modern species from that continent than those from Europe.
- On further study after his voyage, Darwin noted that while most of the animal species on the Galapagos lived nowhere else, they resembled species living on the South American mainland.
- It seemed that the islands had been colonized by plants and animals from the mainland that had then diversified on the different islands.

12 ## While on the Beagle, Darwin read Lyell's *Principles of Geology*.

- Lyell's ideas and his observations on the voyage lead Darwin to doubt the

church's position that the Earth was static and only a few thousand years old.
- Instead, he was coming to the conclusion that the Earth was very old and constantly changing.

13

- After his return to Great Britain in 1836, Darwin began to perceive that the origin of new species and adaptation of species to the environment as closely related processes.
  - For example, among the 13 types of finches that Darwin collected in the Galapagos, clear differences in the beak are adaptations to the foods available on their home islands.

14 ## Wallace and Darwin

- By the early 1840's Darwin had developed the major features of his theory of natural selection as the mechanism for evolution.
- In 1844, he wrote a long essay on the origin of species and natural selection, but he was reluctant to publish his theory and continued to compile evidence to support his theory.
- In June 1858, Alfred Wallace, a young naturalist working in the East Indies, sent Darwin a manuscript containing a theory of natural selection essentially to identical to Darwin's.

15 ## Origin of Species

- Later that year, both Wallace's paper and extracts of Darwin's essay were presented to the Linnaean Society of London.
- Darwin quickly finished *The Origin of Species* and published it the next year.
- While both Darwin and Wallace developed similar ideas independently, the essence of evolution by natural selection is attributed to Darwin because he developed and supported the theory of natural selection so much more extensively and earlier.

16 ## **descent with modification**

- In descent with modification, all present day organisms are related through descent from unknown ancestors in the past.

- Descendents of these ancestors accumulated diverse modifications or adaptations that fit them to specific ways of life and habitats

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18 ## Evolution mechanism

- The other major point that Darwin pioneered is a unique mechanism of evolution - the theory of natural selection.

- Ernst Mayr, an evolutionary biologist, has dissected the logic of Darwin's theory into three inferences based on five observations.
- These observations include tremendous fecundity, stable populations sizes, limited environmental resources, variation among individuals, and heritability of some of this variation.

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- Observation #1: All species have such great potential fertility that their population size would increase exponentially if all individuals that are born reproduced successfully.
- Observation #2: Populations tend to remain stable in size, except for seasonal fluctuations.
- Observation #3: Environmental resources are limited.
- Inference #1: Production of more individuals than the environment can support leads to a struggle for existence among the individuals of a population, with only a fraction of the offspring surviving each generation.

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- Observation #4: Individuals of a population vary extensively in their characteristics; no two individuals are exactly alike.
- Observation #5: Much of this variation is heritable.

21 Not random…

- Inference #2: Survival in the struggle for existence is not random, but depends in part on the hereditary constitution of the individuals.
  Those individuals whose inherited characteristics best fit them to their environment are likely to leave more offspring than less fit individuals.
  Inference #3: This unequal ability of individuals to survive and reproduce will lead to a gradual change in a population, with favorable characteristics accumulating over the generations.

22 Darwin's main ideas can be summarized in three points.

- *Natural selection is differential success in reproduction (unequal ability of individuals to survive and reproduce).*
- *Natural selection occurs through an interaction between the environment and the variability inherent among the individual organisms making up a population.*
- *The product of natural selection is the adaptation of populations of organisms to their environment.*

23 Malthus

- Darwin's views on "overreproduction" were heavily influenced by an essay on human population by Thomas Malthus in 1798.

- Malthus contended that much human suffering - disease, famine, homelessness, war - was the inescapable consequence of the potential for human populations to increase faster than food supplies and other resources.
- The capacity to overproduce seems to be a characteristic of all species, with only a small fraction of eggs developing to leave offspring of their own.

24 ☐ environmental factors filter heritable variations

- Differential reproduction - whereby organisms with traits favored by the environment produce more offspring than do organisms without those traits - results in the favored traits being disproportionately represented in the next generation.

- This increasing frequency of the favored traits in a population is evolution.

25 ☐ Artificial selection

- Darwin's views on the role of environmental factors in the screening of heritable variation was heavily influenced by **artificial selection**.
- Humans have modified a variety of domesticated plants and animals over many generations by selecting individuals with the desired traits as breeding stock.

26 ☐ POPULATIONS evolve

- While natural selection involves interactions between individual organisms and their environment, it is not individuals, but populations that evolve.
- Populations are defined as a group of interbreeding individuals of a single species that share a common geographic area.
- Evolution is measured as the change in relative proportions of heritable variation in a population over a succession of generations.

27 ☐ natural selection operates not to create variation, but to edit existing variation

- For example, resistant insects are favored and non-resistant individuals are not when insecticides are applied.
- Natural selection favors those characteristics in a variable population that fit the current, local environment.

28 ☐ Has to be heritable & meet needs

- Natural selection can only amplify or diminish heritable variations, not variations that an individual acquires during its life, even if these variations are adaptive.
- Also, natural selection is situational.
- Environmental factors vary in space and time.
- Therefore, adaptations for one set of environmental conditions may be useless or even detrimental under other circumstances.

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30 **Natural selection in action: the evolution of drug-resistant HIV**

- While researchers have developed many drugs to combat the human immunodeficiency virus (HIV), drug-resistant strains evolve rapidly in the HIV population infecting each patient.
- Natural selection favors those characteristics in a variable population that fit the current, local environment.
- The evolution of drug resistance or pesticide resistance differ only in speed, not in basic mechanism, from other cases of natural selection.

31 For patients treated with the drug 3TC, which interferes with genome replication in HIV, 3TC-resistant strains become 100% of the population of HIV in just a few weeks.

32 Homologous structures

- In descent with modification, new species descend from ancestral species by the accumulation of modifications as populations adapt to new environments.
- The novel features that characterize a new species are not entirely new, but are altered versions of ancestral features.
- Similarities in characteristics resulting from common ancestry is known as **homology**.
- Comparative anatomy confirms that evolution is a remodeling process via alteration of existing structures, rather than uniquely engineered for their existing function.

33

- Descent with modification is indeed evident in anatomical similarities between species grouped in the same taxonomic category.
- For example, the forelimbs of human, cats, whales, and bats share the same skeletal elements, but different functions because they diverged from the ancestral tetrapod forelimb.
- They are **homologous structures**.

34 Vestigial Organs

- **vestigial organs are** homologous structures of marginal, if any importance to a current organism, but which had important functions in ancestors.
- the skeletons of some snakes and of fossil whales retain vestiges of the pelvis and leg bones of walking ancestors. Homologies that are not obvious in adult organisms become evident when we look at embryonic development.
- For example, all vertebrate embryos have structures called pharyngeal pouches in their throat at some stage in their development.
- These embryonic structures develop into very different, but still homologous, adult structures, such as the gills of fish or the Eustacean tubes that connect the middle ear with the throat in mammals.

35 ☐ Molecular homologies

- The concept of homology also applies at the molecular level (molecular homology) and allows links between organisms that have no macroscopic anatomy in common (e.g., plants and animals).
- All species of life have the same basic genetic machinery of RNA and DNA and the genetic code is universal.
- Genetic code has been passed along all the branches of the tree of live eve since the code's inception If two species have libraries of genes and proteins with sequences that match closely, the sequences have probably been copied from a common ancestor.
- Eg., the number of amino acid differences in human hemoglobin when compared to other vertebrates show the same patterns of evolutionary relationships that researchers find based on other proteins or other types of data.

36 ☐ biogeography

- The geographical distribution of species –
- Species tend to be more closely related to other species from the same area than to other species with the same way of life, but living in different areas.
- For example, even though some marsupial mammals (those that complete their development in an external pouch) of Australia have look-alikes among the eutherian mammals (those that complete their development in the uterus) that live on other continents, all the marsupial mammals are still more closely related to each other than they are to any eutherian mammal.

37 ☐

- For example, while the sugar glider and flying squirrel have adapted to the same mode of life, they are not closely related.
- Instead, the sugar glider from Australia is more closely related to other marsupial mammals from Australia than to the flying squirrel, a placental mammal from North America.
- The resemblance between them is an example of convergent evolution.

38 ☐

- All of the 500 or so endemic species of *Drosophila* in the Hawaiian archipelago descended from a common ancestor that reached Kauai over 5 million years ago.

39 ☐ Relative Time line in Fossils

- The succession of fossil forms is compatible with what is known from other types of evidence about the major branches of descent in the tree of life.
- For example, fossil fishes predate all other vertebrates, with amphibians next, followed by reptiles, then mammals and birds.
- This is consistent with the history of vertebrate descent as revealed by many other types of evidence.
- In contrast, the idea that all species were individually created at about the same time predicts that all vertebrate classes would make their first appearance in the fossil record in rocks of

the same age.
- This is not what paleontologists actually observe.

40 ## Punctuated Equilibrium

- Stephen Jay Gould & Niles Eldredge 1972
- Following Ernst Mayr allopatric/sympatric speciation
- the most sexually reproducing species will show little to no evolutionary change throughout their history
- evolution occurs sporadically by speciation mechanisms
- relatively quickly compared to the species' full duration on earth

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- By attributing the diversity of life to natural causes rather than to supernatural creation, Darwin gave biology a sound, scientific basis.
- As Darwin said, "There is grandeur in this view of life."