VI: Genetics -

Conservation of Diversity within Species

Genetic Variation: Why is it important?

- The rate of evolutionary change is proportional to the amount of genetic diversity available (Fundamental Theorum of Natural Selection; Fisher, 1930)
- Heterozygosity is positively related to fitness of individuals.
- Small populations, whether wild or captive, tend to lose genetic diversity over time.

Genetic Variation: Why is it important? *(continued)*

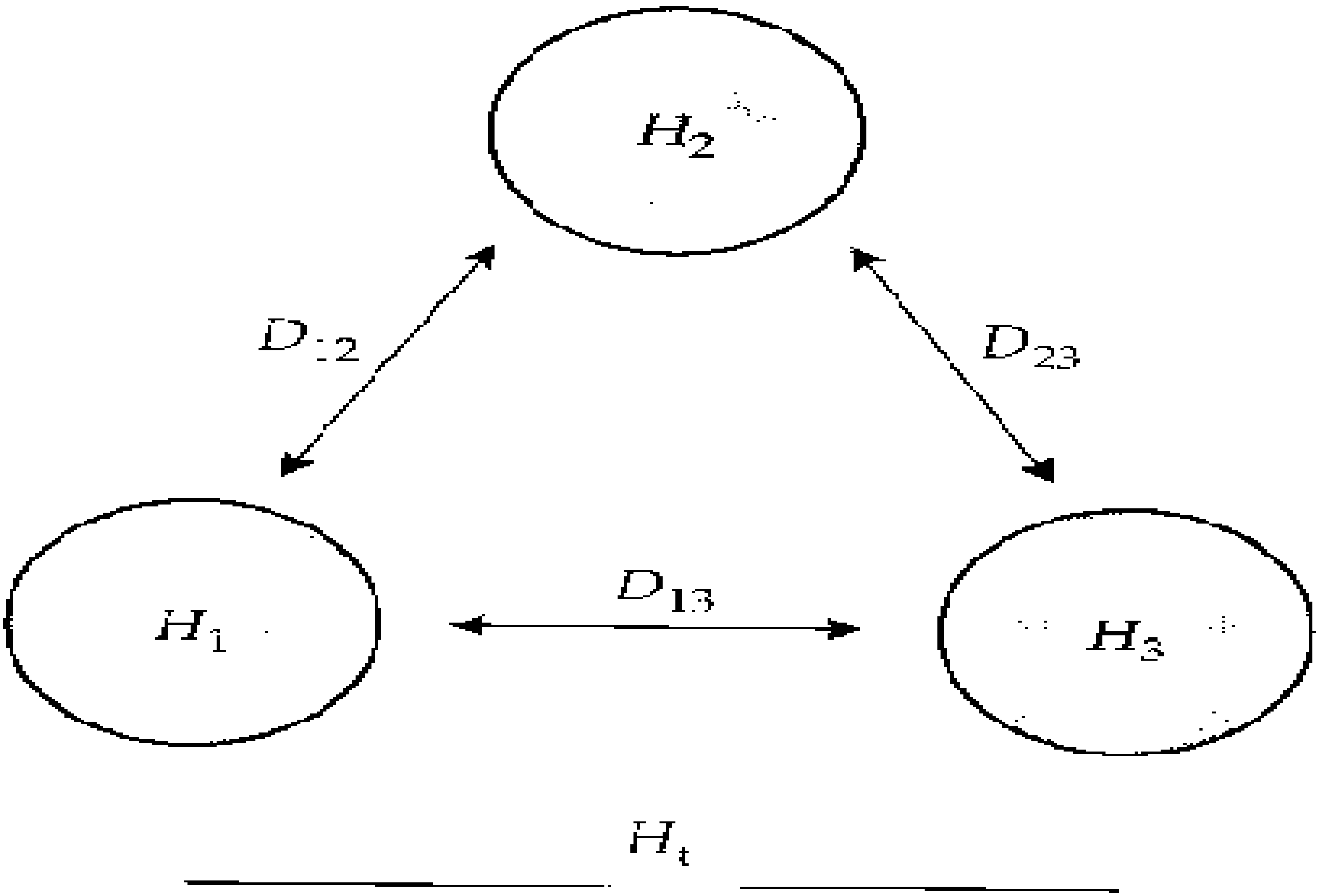
- **Variation within Individuals**
  - **Phenotype is a result of the interaction between the genotype and the environment:**
    - $\mathbf{V_P} = V_g + V_e + V_{ge}$
  - Sources of Individual genetic variation:
    - Sexual reproduction; outcrossing
    - Independent Assortment of chromosomes
    - Recombination (crossing over during meiosis)
    - Mutation
- Variation within Populations

Genetic Variation: Why is it important? *(continued)*

– Population-level genetic variation consists of the types of alleles present and their frequencies in the population or *gene pool.*

Genetic Variation: Why is it important? *(continued)*

- Variation among Populations
  - A species total genetic variation can be partitioned into within species and among species components:
    - $H_t = H_p + D_{pt}$; where H_t is the total genetic variation in the species, H_p is the average diversity within populations, D_{pt} is the average divergence among populations across the species range.



$$H_t = H_p + D_{pt}$$

variation - continued

- The Fitness Consequences of Variation
  - Fitness - the lifetime reproductive success of an individual relative to other individuals in the population.
  - Most population geneticists agree that fitness is enhanced by heterozygosity. Measured levels vary between 0-30%.
  - Causes of increased fitness due to heterozygosity may not be easy to explain, some potential causes are:
    - overdominance (ex: Beta hemoglobin chain and resistance to malaria)

variation continued -

- dominance - masking of deleterious recessive alleles; ex: inbreeding depression.

– Among population divergence may play a critical role in local fitness and population survival:

- Local adaptation is common and may lead to speciation.
- *Coadapted-gene complexes* may arise in local populations (see Templeton essay).
    - outbreeding depression due to coadaptation (owl monkey)
    - local adaptation (Ibex)

Loss of Genetic Variation

- Reduced genetic diversity within populations can arise from four factors that are a function of population size:
  - founder effects
  - demographic bottlenecks
  - genetic drift
  - inbreeding

Loss of Genetic Variation *(continued)*

- The *effective population size* can be reduced by:
  - uneven breeding sex ratios
  - uneven reproductive success of females
  - major declines in the population size
  - Heterozygosity is expected to be lost at a rate of 1/2N per generation in the "idealized" population. All of the above factors would increase the rate of loss of heterozygosity (see Allendorf essay on *Ursus arctos horribilus)*

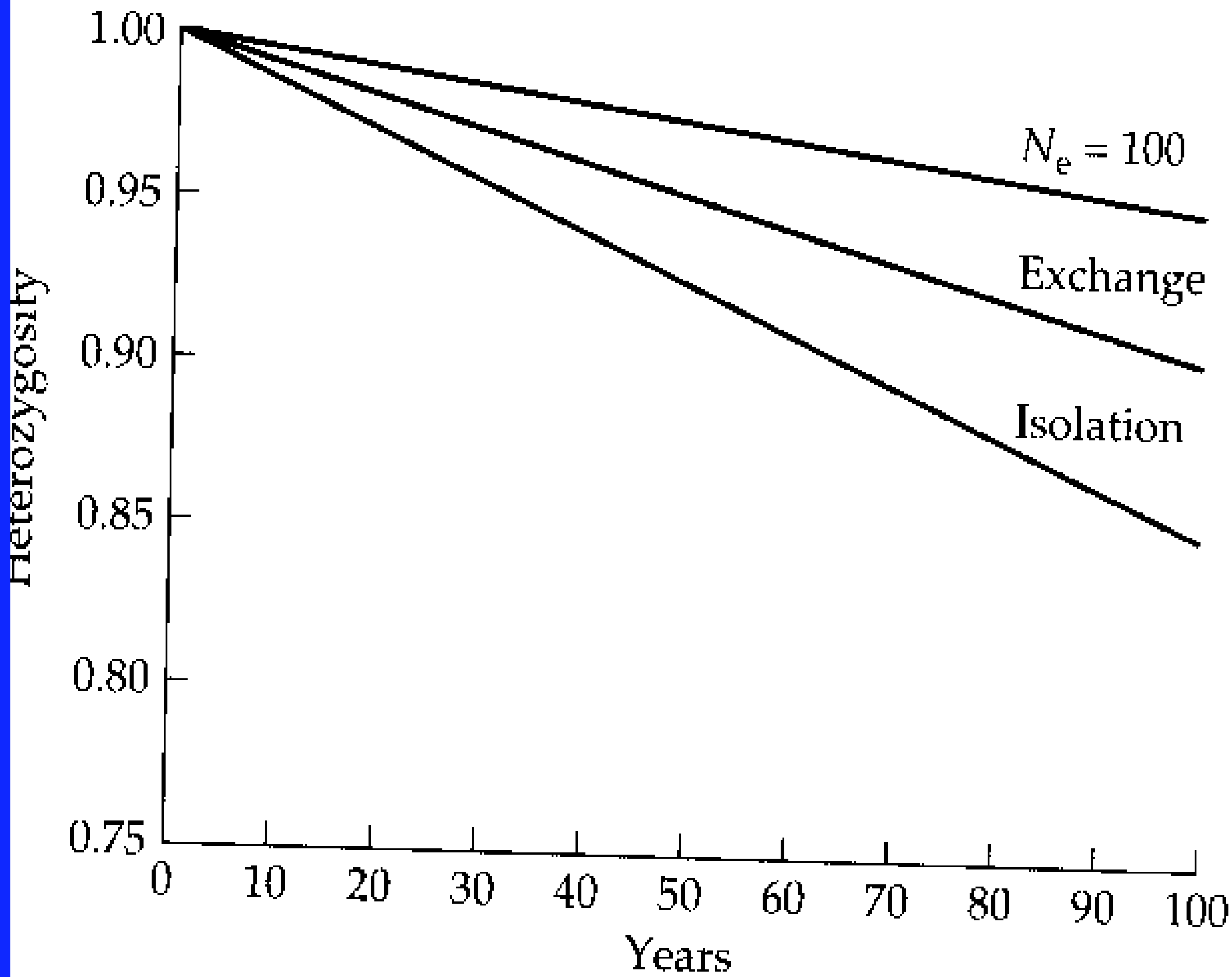


Figure A Expected rate of loss of heterozygosity in a population of 100 grizzly bears. The top line shows the expected rate of loss if the population behaved as an ideal population of 100 individuals. The bottom line shows the rate of loss estimated by computer simulations in an isolated population of 100 bears. The middle line shows the effect of introducing 2 unrelated bears every generation (10 years) into the population of 100 bears.

loss of genetic variation -continued

- Small isolated populations will lose genetic diversity at a rate of approximately $1/2N_e$ per generation.

Management of Genetic Variation in Natural Populations

- Time scales of genetic conservation
  - extinction avoidance
  - maintenance of adaptive evolutionary change
  - maintenance of capacity for continued speciation

Management of Genetic Variation in Natural Populations *(continued)*

- Units of Conservation
  - What units do we protect?
    - Deme - local, randomly interbreeding group of individuals.
    - Metapopulations - networks of populations that have some degree of intermittent or regular gene flow among geographically separate units.
    - Species - US Endangered Species Act, "any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature".
    -

management - continued

- Evolutionary Significant Unit (ESU) - Waples (1991) defined this as a population that:
  - is reproductively isolated from other conspecific population units and
  - represents an important component in the evolutionary legacy of the species.
- Hierarchial Gene Diversity Analysis
  - species can be visualized as having a "spatial genetic architecture".
  - Example: riverine species since rivers form a natural geographic structure (first order, second order, etc.)

management continued -

- distance can be used as a hierarchial component
- data used in hierarchial analysis: allozyme electrophoresis, karyotype analysis, mitochondrial DNA (mtDNA), DNA sequencing
- Polymerase chain reaction (PCR) can be used to amplify DNA samples, i.e., noninvasive sampling can be done (blood, hair , fin clips, single feathers, fecal samples).

- Biogeographic Models of Gene Flow
  - The level of genetic divergence in populations is the product of N_e and m (m = migration rate, proportion of individuals exchanged among populations per generation).
  - If N_e X m>1, local populations will tend not to diverge significantly (genetic drift is important in small populations)
  - The amount of migration necessary to maintain a certain level of divergence can be estimated by the following equation:
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- $D_{pt}/H_t = 1/(4N_e m + 1)$

– The 50/500 rule: N_e of at least 50 is necessary to preserve diversity in the short term; 500 to avoid genetic drift in the long term. The effects of mutation on inbreeding could increase these estimates by an order of magnitude.

- Guidelines for Conservation Practices
  – Large effective population sizes are better than small ones.
  – Avoid managing for unnaturally small populations (drift and inbreeding)

management continued -

- Management should consider the genetic history of the population.
- Low diversity itself is not cause for alarm; sudden losses of diversity are of concern.
- Avoid artifical selection in captivity.
- After a population crash, encourage population growth
- Avoid possible outbreeding depression.
- Avoid introduction of exotic alleles.
- Avoid selection in harvesting wild stocks.
- Captive stocks are no substitute for wild ones.