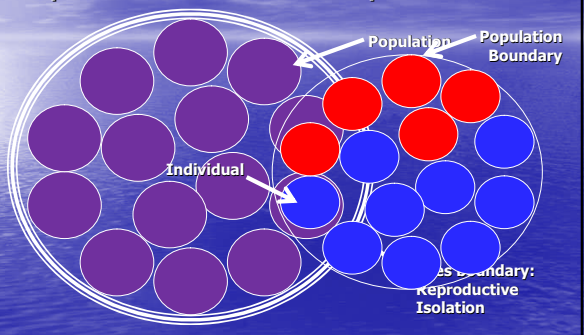
How do genes get distributed across the species?

They sort out by populations

- What is a population?
  - A population is a subdivision of a species
  - A population is a local community of individuals where mates are usually found
  - A population shares a common gene pool
  - A population has continuity through time

Population ≠ Race

Populations within a species



Garn (1971) on population

In contrast to geographical races which are geographically delimited population collections, *local races* correspond more nearly to the breeding populations themselves. Whether isolated by distance, by geographical barriers or by social prohibitions, local races are totally or largely endogamous, and the very small amount of gene-flow ordinarily comes from contiguous and related local races.

Local Races or populations

(Garn 1971)

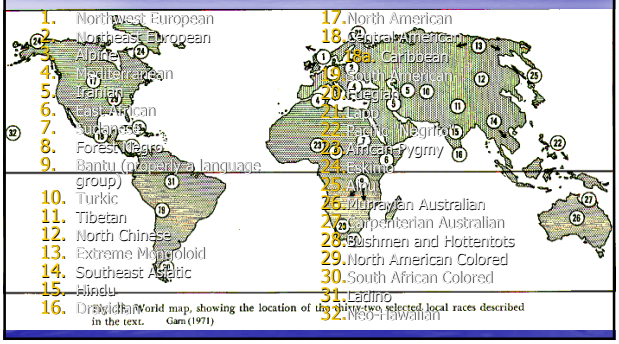


Fig. 1. World map, showing the location of the thirty-two selected local races described in the text. Garn (1971)

How do we know if people belong to the same population?

- They need geographical proximity
  - Must be able to meet to mate!
- Share a common language
  - Communicate with one another
- Share ethnicity, culture, religion
  - More likely to mate if sharing history and values

Estimated ~7,000 human populations in the world at the start of the 21st Century

Where do we find our mates?

- Until recently most people stayed in the place they were born and married someone from nearby
- The last half of the 20th century was characterized by the breakups of local population isolates
- This major change in breeding pattern has resulted in increased genetic heterogeneity

Distribution of Genes in Populations

- Mating patterns
  - Any non-random mating will produce either increases or decreases in Homozygosity
  - Assortative Mating
    - Mating at greater than random frequencies between individual with like (Positive) or unlike (Negative) genotypes
  - Inbreeding
    - Mating at greater than random frequencies between biologically related individuals

Positive Assortative Mating

Trait	Spouse Correlation
I.Q.	0.47
Ear lobe length	0.40
Waist circumference	0.38
Height	0.28

- As with most mammals, humans tend to mate with like individuals, particularly for visible or noticeable traits

Negative Assortative Mating

- Negative assortative mating is rare in mammals
  - Rodents have a preference for mates with dissimilar HLA haplotypes
    - Variability in HLA haplotypes maximizes potential immune system response
    - Mice detect HLA by smell of urine
  - Finding confirmed for humans among Hutterites
    - Humans may detect this through the smell of sweat on the body
      - Mating odor preferences may be HLA-linked in human

Inbreeding

- **Incest taboos** prohibit mating between closely related individuals, making inbreeding less common than random
  - Increases heterozygosity
- **Cousin marriage preferences,** make inbreeding more common than random
  - Increases homozygosity
  - Polygamy and fumarase deficiency

Distribution of Genes in Populations

- **Mutation** is the source of all new genetic variation
- **Migration** affects genetic structure by mating between members of different populations
- **Genetic drift** is change in gene frequencies based on random events in finite populations
- **Natural selection** occurs in response to environmental stressors

Mutation

- Mutation is a rare event, so it has small quantitative effects but potentially large qualitative effects
  - Estimate of the average human genome mutation rate is ~2.5 x 10-8 mutations per nucleotide per generation (25 mutations per billion nucleotides per generation)
- However, even small changes to the sequence of nucleotides in the DNA can have significant repercussions in terms of protein structure and function

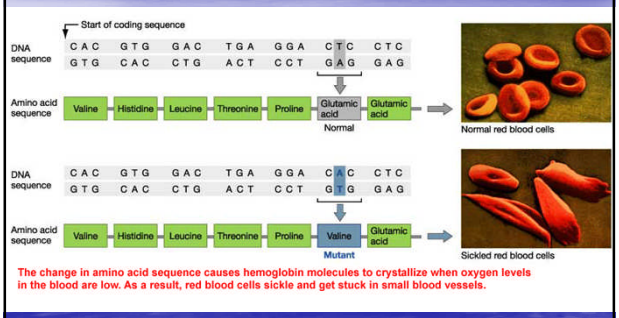
Sickle Cell Anemia

- Sickle cell anemia is a severe genetic condition caused by a **point** mutation: the change in one nucleotide within the sequence of 438 bases coding for the hemoglobin beta chain
- The transversion mutation in the 17th nucleotide from a Thymine base to an Adenine base causes a shift in the 6th amino acid from glutamic acid to valine

Sickle Cell Anemia

- The change of one amino acid results in hemoglobin that has a tendency to clump together and destroy Red Blood Cells
- This produces a life-threatening disease that has only come under good control by modern medicine in the last several decades

Point Mutation



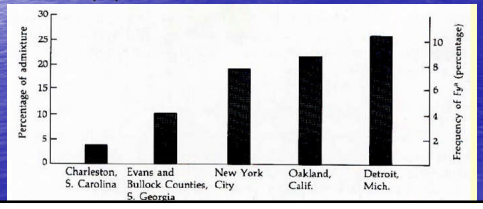
The change in amino acid sequence causes hemoglobin molecules to crystallize when oxygen levels in the blood are low. As a result, red blood cells sickle and get stuck in small blood vessels.

Migration or gene flow

- Gene Flow, the intermarriage or mixing between populations, has the effect of altering allele and genotype frequencies so that the two (or more) populations involved come to resemble each other in terms of genetic frequencies

Admixture in African Americans

- Admixture has resulted in significant genetic changes in the African American population
- The Duffy blood group allele, Fy^a, was absent in enslaved Africans brought to the US
  - In West Africa the allele is close to 0%
  - The allele frequency is about 40% in US Whites
- Based on this, the % of white admixture in the African American population has been estimated:



Selection

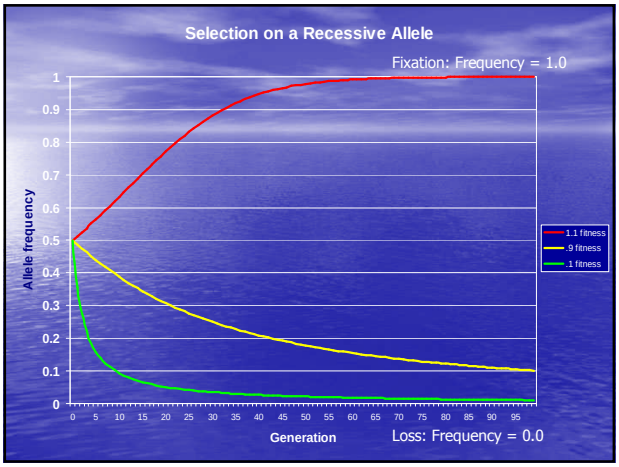
- Selection causes changes in allele and genotype frequencies from one generation to the next due to differential net reproductive success of individuals with different genotypes
  - If individuals with genotype AA consistently have twice as many offspring as individuals with AB and BB genotypes, the frequency of the A allele will increase and eventually, everyone will have the AA genotype

Selection

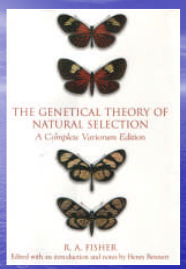
- There are two elements contributing to the differential reproductive success of individuals with differing genotypes
  - Viability or survival: individuals must survive to maturity in order to be able to reproduce
  - Fertility: individuals must produce offspring in order to pass on their genes
- The genotype producing the most offspring on average is the most fit

Natural Selection

- Natural selection is a two-step process
  - Production of variation (mutation)
  - Differential reproduction of favorable variants (selection)
    - Fitness is a measure of relative reproductive success
      - Fitness = 1 means no selection
      - Fitness < 1 means allele selected against—should disappear from the population
      - Fitness > 1 means the allele is favored by selection—should go to fixation (exclusion of other alleles from the population)



The fate of a mutant in an infinite population



R.A. Fisher. The distribution of gene ratios for rare mutations (1930)

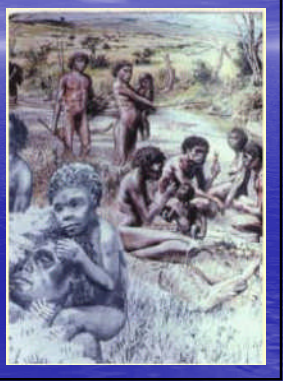
- If a mutant has a selective advantage of 0.01, there is 78% chance for it to be lost in the first seven generations
  - And a 2% chance of spreading to the entire population
- Most beneficial mutations do not fix in the population!

Why do beneficial genes disappear?

- Genetic Drift
  - A finite population size is subject to chance or random influences on gene frequencies from one generation to the next
    - Smaller the population, the larger the effect
  - Founder effect is a small sample of a larger population that becomes a founder of a new population

Genetic Drift and Human Evolution

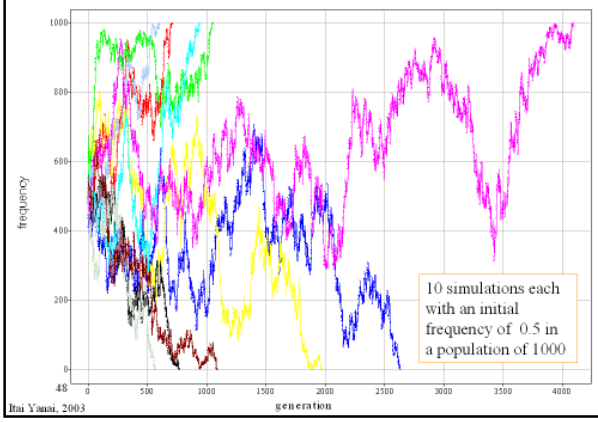
- Until recently, most humans lived in small, genetically isolated hunter-gather groups of perhaps 20-30 people
- Gene frequencies in groups of this size are highly susceptible to the effects of genetic drift
- As a result, much of the genetic variation in modern human populations may be a result of random processes such as genetic drift and natural selection



200 trials with a population size 100 and an initial frequency of 0.01

- **Two fixations out of 200 trials**
  - **1% chance of a "neutral" mutation becoming fixed in a population of 100!**
  - **99% chance of loss**

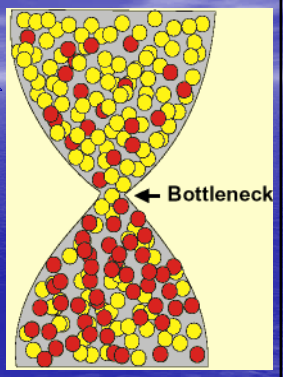
Genetic drift removes variation from the population



Bottleneck Effect

- This is a genetic sampling error that occurs when a catastrophic event reduces the size of a population to a few individuals
- The small number of survivors will almost certainly differ genetically from the ancestral population (e.g. rare alleles will be lost)
- The survivors will give rise to a new population that differs genetically from the one that existed before the catastrophe

Time

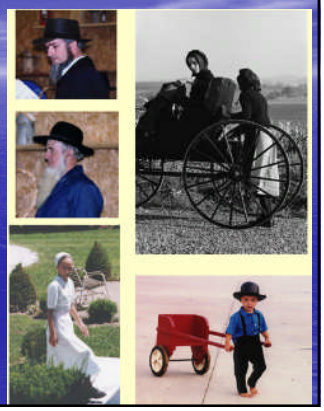


Founder Effect

- The genetic difference between the gene pool of a population and that of a newly isolated subpopulation from the same group
  - When a small number of individuals form a new population they have a random sample of the genes of the larger population they are derived from
    - Allele presence and frequencies may vary significantly from the parent population
- As the size of the founding population increases, the magnitude of the founder effect decreases
  - A recent estimate of the founding population of Native Americans was ~80 individuals!

Founder Effect

- The founder effect can be seen in geographically isolated populations as well as in socially isolated religious groups such as the Amish and Dunkers



Conclusions

- Genes are distributed in populations
- Populations differ from one another in the frequencies of different alleles
- The ultimate source of new genetic variation is mutation
- Gene flow makes population resemble one another
- Genetic drift and natural selection reduce variation in specific ways
  - Genetic drift is not related to environment, natural selection is