Overview of Lecture: Microevolution I

Read: Text Ch 19

Microevolutionary processes and patterns
Some important examples of contemporary evolution in action.

• evolution in action
• evolution of Bacteria on a “Mega-Plate”
• 12 Days of Evolution
• correlated variation in genotypes and phenotypes – heritability
• classic Mendelian vs complex quantitative traits – SNPs and GWAS
• phenotypic selection: disruptive, directional & stabilizing
• genetic and phenotypic responses to selection across generations
• traditional approach to estimating genetic heritability of traits – IQ scores
• genomic approaches –
  **SNPs** – Single Nucleotide Polymorphisms, and
  **GWAS** - Genome Wide Association Studies
• The search of “Gay genes”
• Why Making A 'Designer Baby’ will be difficult
• signatures of selection in contemporary humans
• heritable happiness! (“happiness glasses”?)
Learning Goals:

1. Understand and be able to use examples to explain …
   What is evolution by natural selection (ENS)? What are the fundamental, necessary and sufficient conditions for ENS? Use examples to illustrate stabilizing, directional and disruptive phenotypic selection.

2. Be able to use examples and arguments from the lecture and supplemental materials to explain Why Making A 'Designer Baby' Would Be Easier Said Than Done

3. Be able to use examples to explain why showing that a trait has some level of genetic heritability, for example IQ score or subjective happiness, doesn’t imply anything about the potential for beneficial interventions.
There are only two models for the origin of humans: evolution and creation. If creation occurred, it did so just once and there will be no "second acts." If evolution occurs, it does so too slowly to be observed. Both theories [creationism, evolution by natural selection] are accepted on faith by those who believe in them. Neither theory can be tested scientifically because neither model can be observed or repeated.

https://www3.beacon-center.org

The BEACON Center for the Study of Evolution in Action is an NSF Science and Technology Center with the mission of harnessing the power of evolution in action to advance science and technology and benefit society.
What did you learn from this experiment/video?
Anything helpful, interesting, surprising, puzzling in this?
Natural selection produces evolutionary change

As a result, the population gradually comes to include more and more individuals with the advantageous characteristics. In this way the population evolves across generations and becomes better adapted to its recent past local circumstances. - in a later lecture we will discuss “adaptation” and constraints to perfection.

Evolution can result from any process including but not limited to natural selection that causes a change in the genetic composition of a population.

Note: this implies that not all evolutionary change is adaptive. Ex: the DNA triplet code is redundant: 4x4x4=64 sequences but only ~23 amino acids. Synonymous substitutions at the 3rd position in some DNA triplet codons are “silent,” having no effect on the coded Amino Acid. Ex: TTT and TTC are redundant, both specify Phenylalanine. Redundant codons can evolve with little or no impact on fitness. The rate of accumulation of synonymous substitutions serves as a null model for mutation and drift, to compare to selected, non-synonymous substitutions that change AA sequence and protein structure.
An organism exposes its **phenotype** ... not its **genotype** to the environment.

Classical Mendelian traits:

Modern genomic perspective:

**GWAS**: is there any statistical correlation across many individuals between DNA\(a\) and Phenotype\(b\)?

[ *note: neither figure considers the role of environmental effects E or GxE interactions on phenotype or fitness* ]

[ *GxE interactions & G-E correlations make the meaning of heritability problematic* ]
Modern genomic perspective: **SNPs – Single Nucleotide Polymorphisms, and GWAS - Genome Wide Association Studies**

which might be associated with a phenotypic trait

![Genotype Space](http://pleiotropy.fieldofscience.com/2012/09/genotype-phenotype-maps-and-mathy.html)

**Note:**

1. **Pleiotropy:** “one to many:” differences in DNA at a location might influence variation in many phenotypic traits.
2. **Epistasis:** “many to one:” each phenotypic trait might be influenced by variation at many locations in the DNA (including non-transcribed “control” regions). Often variation in each location has a very small effect on the phenotype.
The top panels show the populations before *(phenotypic)* selection has occurred … those favored by selection are shown in light brown.

big benthic (shallow w/ plants) little limnetic (open water) sticklebacks
The pre-genomics approach to estimating how much phenotype depends on genotype.

**The heritability of IQ.** *(note: IQ is a culturally laden test score)*


IQ heritability \([h^2]\), the portion of a population's IQ variability attributable to the effects of genes remains controversial.

What we have are patterns of

<table>
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<th>Relationship</th>
<th>Raised</th>
<th>Corr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monozygotic twins</td>
<td>Together</td>
<td>0.85</td>
</tr>
<tr>
<td>Monozygotic twins</td>
<td>Apart</td>
<td>0.74</td>
</tr>
<tr>
<td>Monozygotic twins</td>
<td>Together</td>
<td>0.60*</td>
</tr>
<tr>
<td>Dizygotic twins</td>
<td>Together</td>
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</tr>
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<td>Siblings</td>
<td>Together</td>
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<tr>
<td>Siblings</td>
<td>Apart</td>
<td>0.50</td>
</tr>
<tr>
<td>Midparent/child</td>
<td>Together</td>
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</tr>
<tr>
<td>Single-parent/child</td>
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</tr>
<tr>
<td>Single-parent/child</td>
<td>Apart</td>
<td>0.18</td>
</tr>
</tbody>
</table>

There are various ways to est \(h^2\) from these correlations, including the midparent-offspring regression, which gives \(h^2 \sim 0.5\)

Is the IQ glass “half full of genetic similarities and half full of environmental differences?”

Intelligence is challenging to study, in part because it can be defined and measured in different ways. Most definitions of intelligence include the ability to learn from experiences and adapt to changing environments. … to reason, plan, solve problems, think abstractly, and understand complex ideas. [poorly defined]

Researchers have conducted studies to look for genes that influence intelligence. Many of these studies focused on similarities and differences in IQ [test scores] within families, particularly looking at adopted children and twins. These studies suggest that genetic factors underlie about 50 percent of the difference in intelligence [test scores] among individuals. Other studies have examined variations across the entire genomes of many people (an approach called Genome-Wide Association Studies or GWAS) to determine whether any specific areas of the genome are associated with IQ. These studies have not conclusively identified any [particular] genes that underlie differences in intelligence. [but ?]

It is likely that a large number of genes [of very small effect] are involved … Intelligence is also strongly influenced by the environment.

A person’s environment and genes influence each other, and it can be challenging to tease apart the effects of the environment from genetics.
Is there a "gay gene"? Major new study says no

BY DENNIS THOMPSON
AUGUST 29, 2019 / 8:33 PM / HEALTHDAY

There's no such thing as a single "gay gene" that drives a person's sexual behavior, concludes the largest genetic study [GWAS] ever conducted on the issue. Instead, a person's attraction to those of the same sex [phenotype P] is shaped by a complex mix of genetic [G] and environmental [E] influences, similar to what's seen in most other human traits, [all genetic G-P associations explain-predict only a few % of variation in P; as usual, variation in E is not measured in this GWAS and therefore GxE is also not considered] … "It's effectively impossible to predict an individual's sexual behavior from their genome," …

Search For 'Gay Genes' Comes Up Short In Large New Study

RICHARD HARRIS August 29, 2019

A huge new study finds a faint hint of genetic variation that may be linked to same-sex behavior. The study broadly reinforces the observation that both biology [G] and a person's environment [E] influence sexuality, but the results reveal very little about that biology. [knowing G gives little predictability]
As scientists learn more about the complex way genes combine and work together to create human traits, the idea of "designer babies" becomes less and less likely.

Back in the day of Gregor Mendel, the monk who [studied] the traits of the pea plants in his 19th century garden, it seemed that traits were based on simple elements (later dubbed "genes").

But by the 1920s, it was becoming clear that
Natural selection in humans is happening more than you think

Many [phenotypic] traits like higher body mass index are linked to having more kids [one measure of fitness] and show genetic basis [are at least partially heritable].

Many traits vary among different members of a population … from body size to hair colour, and those differences are often linked to differences in genes. Natural selection occurs when some of those traits help some individuals survive and reproduce more than others.

Natural selection is still influencing the evolution of a wide variety of human traits, from when people start having children to their body mass index, reports a study published Monday in the journal Proceedings of the National Academy of Sciences.

"It's surprising to some scientists. I think it's probably even more surprising to the general public," acknowledges lead author Jaleal Sanjak, who just completed his PhD in evolutionary biology at the University of California Irvine. "It's pretty neat."
Evidence of directional and stabilizing selection in contemporary humans
J.S. Sanjak et al. PNAS January 2, 2018. 115 (1) 151-156;

Directional selection results in covariance \[\sim \text{a correlation}\] between the trait and fitness and can lead to changes in the mean value of a phenotypic trait in a population. If phenotypic variation for the trait is caused by genetic factors, \[\text{a G main effect}\] then directional selection can result in changes in the genetic composition of a population. \[\text{this is the definition of evolution by natural selection}\]

Phenotypes may also be subject to stabilizing selection or disruptive selection, which are both nonlinear forms of selection. The key distinction between stabilizing and disruptive selection is whether the relationship between fitness and a phenotype is concave down or up, respectively. Stabilizing selection … will tend to reduce phenotypic variation while disruptive selection will tend to increase it.

The purple dashed line is some measure of fitness, ex: relative Lifetime Reproductive Success (rLRS)
Evidence of directional and stabilizing selection in contemporary humans

J.S. Sanjak et al. PNAS January 2, 2018. 115 (1) 151-156;

Here, we analyze the **phenotypic** and **genetic** correlates of **relative lifetime reproductive success (rLRS)** - the individual lifetime reproductive success divided by the mean [*a proxy for fitness*] - in the UK Biobank (UKB).

The dataset consists of over 500,000 individuals from the United Kingdom who have been genotyped at common SNPs [what are these?] and clinically phenotyped for many different traits.

These data provide **paired genotype and phenotype** samples large enough to accurately measure additive genetic correlation [*but little info on environment E*] between [*patterns of SNPs*] and many heritable complex [*phenotypic*] traits.

We estimate linear (β) [*directional*] and quadratic (γ) [*stabilizing or disruptive*] selection gradients by regressing rLRS onto phenotypes and squared phenotypes.

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The observed signals of directional selection [many significant linear regressions (\(\beta\))]

12 traits in females and 14 traits in males have a significant nonlinear selection gradient estimate (\(\gamma\)) - skewed toward negative values [corresponding to stabilizing selection]

What does this suggest about the distributions of phenotypic traits in contemporary human populations (in the UKB)?

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Just fyi – here are the traits; you don’t need to memorize these things. The ones in red mediate genetic correlations with $r_{LRS}$

**Abbreviated trait descriptions:**
age at menarche (AAM),
age at first birth (AFB),
age at menopause (AMP),
body-fat percentage (BFP),
bone mineral density (BMD),
body-mass index (BMI),
basal metabolic rate (BMR),
birth weight (BW),
diastolic blood pressure (DBP),
educational attainment (EA),
forced expiratory volume (FEV),
fluid intelligence score (FIS),
forced vital capacity (FVC),
hip circumference (HC),
hand grip strength (HGS),
height (HT),
mean time to correctly identify matches (MTM),
neuroticism score (NS),
peak expiratory flow (PEF),
pulse rate (PR),
pulse-wave arterial stiffness index (PWA),
pulse-wave peak-to-peak time (PWP),
pulse-wave reflection index (PWRI),
systolic blood pressure (SBP),
speech reception threshold (SRT) estimate, waist circumference (WC),
waist-to-hip ratio (WHR),
and weight (WT).
… feelings of well-being run in families.

Studies based on surveys of twins and families have estimated
~40% of the variance in happiness (or “subjective well-being” SWB)
between people is influenced by genetic factors.
(based on phenotypic correlations and kinship as a measure of genetic correlation)

Now, behavioral geneticists, economists and social scientists report …
Meike Bartels and her team examined a pool of about twelve thousand unrelated,
fully genotyped people (from the Swedish Twin Registry and the Rotterdam Study).
They {found} single nucleotide polymorphisms (SNPs ~”genetic markers”)
associated with subjective well-being {SWB = the phenotypic trait}.

They estimated “… heritability” … through a relatively new statistical test: …
~12-18% of SWB variance is associated with additive genetic factors {markers} …
Although our genes play a role in determining our general level of happiness,
the team rejects any claim that interventions to increase SWB are useless.
The authors write … “the very same genotype may cause a person
to grow to 5 feet or 6 feet tall, depending on nutritional intake.”

In 1979 Arthur Goldberger offered an analogy:
Poor eyesight is largely determined by genetics,
but the right set of glasses can restore near 20/20 vision.

Put on your Happiness Glasses!