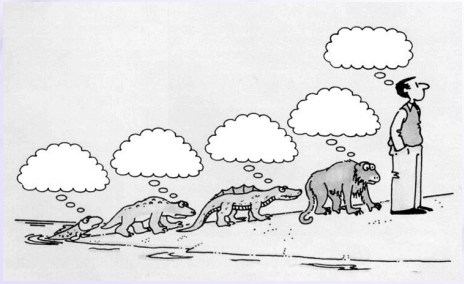
Origins: Evolution, Genetics & Development

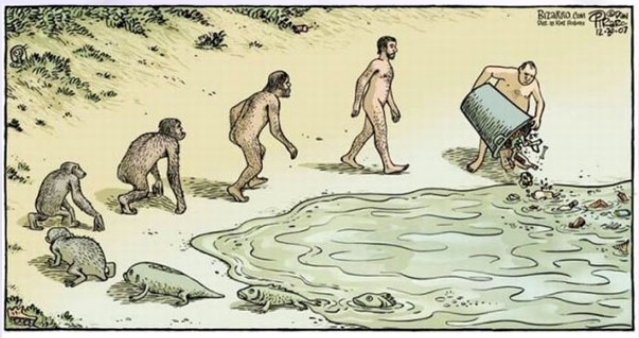
Randall C. O'Reilly

Evolution?



How does a fish EVER give birth to something other than a fish!?

☺

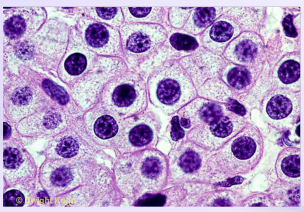


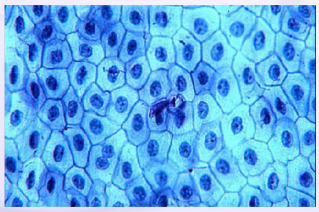
Hard to Fathom

It took a ***long*** time (longer than you can imagine!)

- very, very gradual change..

We don't think of ourselves as cells (which is frog, human?):





Evolution and Lego

The same parts, reconfigured..

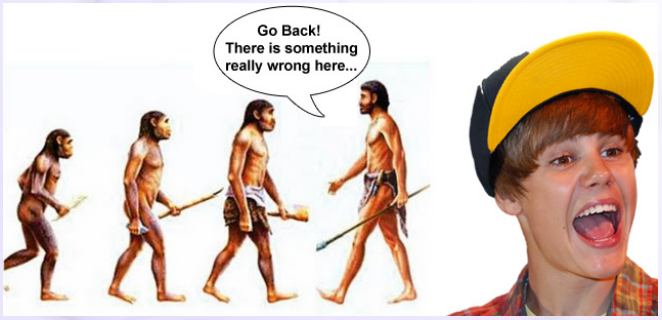
Evolution operates on an elaborate "instruction booklet" for constructing bodies from basic building blocks – the instruction book is subject to random and powerful hacking..

Fast Forward..

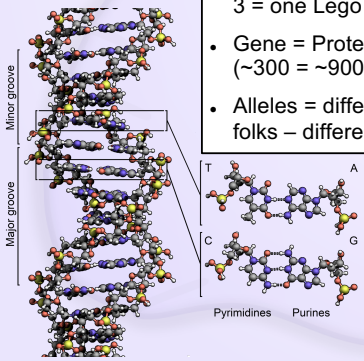
Soft robots evolving in front of your eyes:

https://www.youtube.com/watch?v=z9ptOeByLA4

It is not an optimization process! (just everyone trying to get by..)



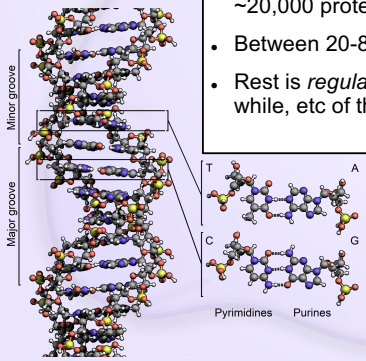
The Instructions



Genes = Lego instruction pages

- Base pair (G,C,T,A: Gattaca, nucleotide) 3 = one Lego brick (amino acid)
- Gene = Protein = sequence of amino acids (~300 = ~900 bp's, but genes ~27,000 bp)
- Alleles = different instructions for different folks – different gene variants

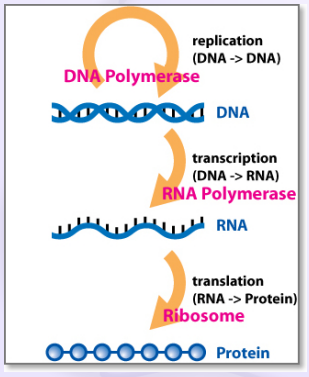
The Instructions



Genes = Lego instruction pages

- Only 1.5% of human DNA codes for proteins, ~20,000 proteins in all (like most animals)
- Between 20-85% of DNA may be "junk"
- Rest is *regulatory* & *control*: if, then, else, for, while, etc of the genetic program!

RNA and DNA



- DNA makes RNA (Transcription)
- RNA makes proteins
- (Translation)
- Proteins make us

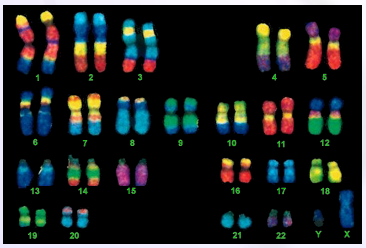
98.8% Human?

Proteins largely the same, but regulatory / junk areas differ by ~5%

Chromosomes etc

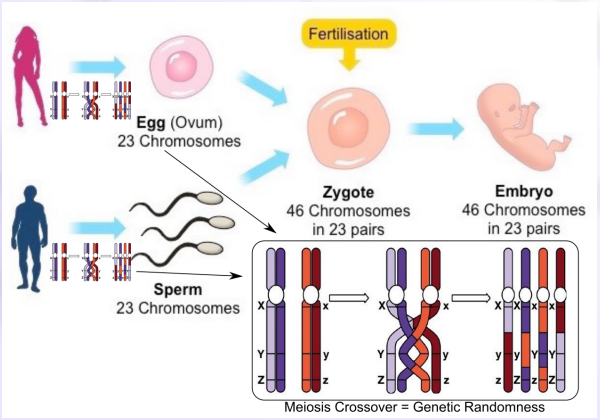
2x of everything:
mom + dad = 2

Dominant vs. recessive:
DD, Dr, rD, rr =
¾ dominant, ¼ rec.

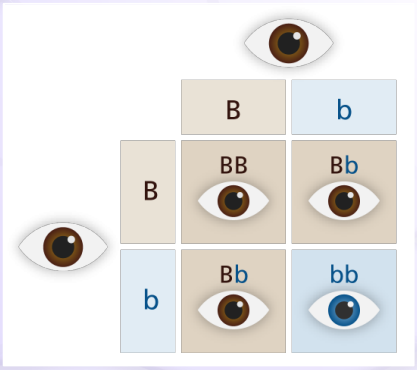


All the bad stuff is recessive: why incest is risky!

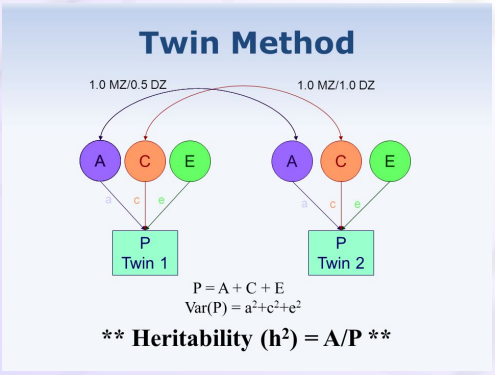
Sex = Genetic Randomness
(but mixing is on *grand*parent's genes!)



Dominant vs Recessive Logic

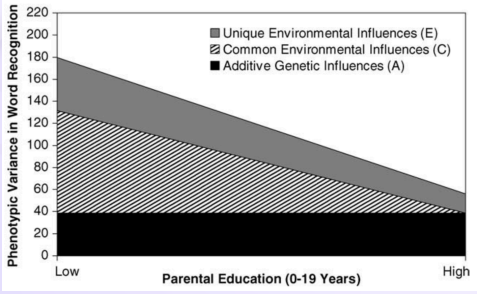


Heritability estimated from Twins



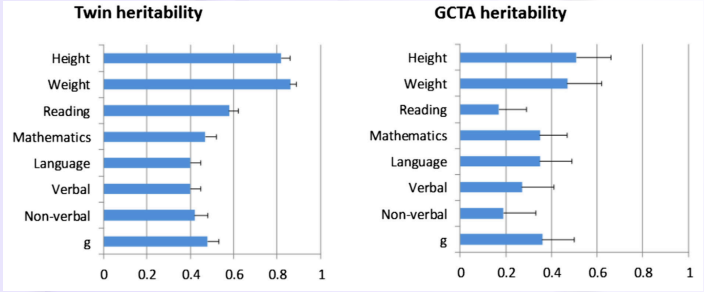
A = Additive genetic factor; C = Common (shared) environment;
E = Unique environment

Heritability is tug-of-war between genetic and environmental factors



If environmental influences go down, measured amount of genetic heritability goes up *even if the actual genetic influence remains exactly the same!!!*

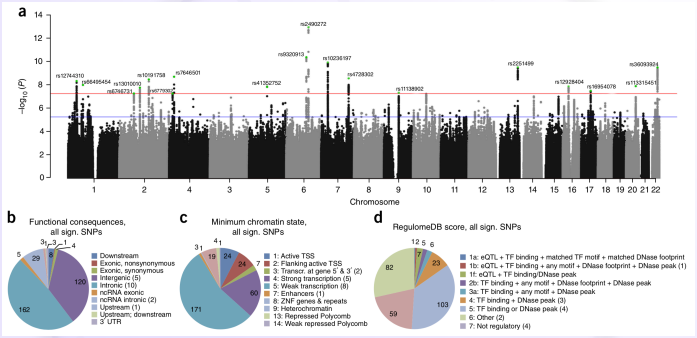
Heritability



h^2 = proportion of *variance* explained by genetics

Twin studies = 2x direct genetic contributions – *missing heritability* problem, or *excess* heritability in twins!

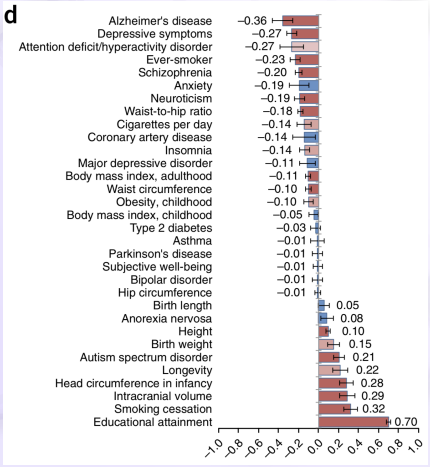
Genes and IQ



Genome-Wide Association Study (GWAS) for IQ: No single gene explains much, but if you put them all together, ~20% heritability.

IQ = *Phenotype: observable characteristics or traits*

IQ Gene Associations



Gene / Environment Correlations

Overestimate heritability because genes influence environments!

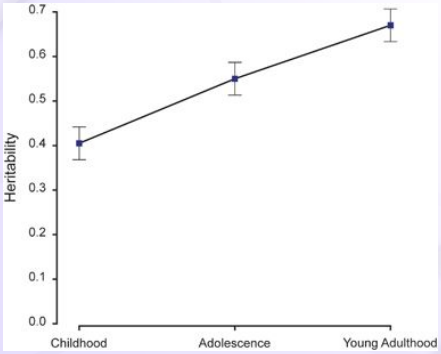
Geeks seeking geeks do geeky things together which makes them even geekier, and thus more likely to *rule the world*!

- And, yes, non-geeks shunning said geeks, further reinforcing said geekiness (reactive vs. active).

Everything is a Nature/Nurture Interaction

- Can't be smart if you can't eat.
  - Deprivation of the basics leads to developmental problems no matter what genes you have
- Parents give you genes and, for most, your early environment (c.f., twins reared apart!)
- Brain is highly plastic (adaptive): h^2 of IQ gets *larger* over time: it's about *learning*!

IQ Heritability goes UP over time!



Also: Flynn effect: IQ is going up over decades

Nature Nurture Summary

- **Genes:** made from DNA, determine how body develops (the program)
  - **Genotype** = all genes; **Alleles** = different versions of gene
- **Phenotype:** measurable traits (IQ, ADHD..)
- **Behavior(al) genetics:** study of genetic vs. environment influence on behavior, etc
  - Identical vs. fraternal twins vs. unrelated siblings
- **Heritability (h^2):** amount of *variance* between people that is due to genes (0..1) (low variance = more h^2)
  - Almost everything has some heritability.. often ~.5

Nature Nurture Summary

- **Environment:** (shared = family, vs. unique) – everything outside of genes that affects you..
- Everything (genes, environment) typically has an effect on everything.. e.g., IQ = 50/50
- **Gene / Environment Correlation:** environment affected by genes.. (geeks!)
- **Gene / Environment Interaction:** different people respond differently to same environment

Development

- How do we go from jello to genius?
  - Babies are complete idiots (*Onion* headline)
  - Every one of you is capable of amazing feats of cognition that cannot be captured in current AI – and it all develops automagically – how!?
- What forces shape our development?
  - Social, parental, genetic, etc

Development is Amazing

We are (fascinated by) butterflies: baby *you* is as different from adult *you* as a caterpillar and a butterfly!

https://www.youtube.com/watch?v=InPRQNQBj5c

https://www.youtube.com/watch?v=ZTjHLF3xKWo

Babies are Idiots

https://www.youtube.com/watch?v=IhHkJ3InQOE

(my son Kai)

https://www.youtube.com/watch?v=0L7xzcvJzZc

(my son Max)

Development = big, obvious effects – good window into components of cognition

What Develops, When?

Just think about everything you know:

- Sensory-motor skills: recognizing, naming objects, reaching, manipulating, walking, talking, running…
  - Many animals born with these skills, why do we take so long?
  - You can't even control your bowels for 3 full years!?
- CCC = Controlling your behavior: first there are no tantrums, then there are, then they get less frequent.
- Socialization: mine mine mine! -> share, play together…
- And then you go to school, college…

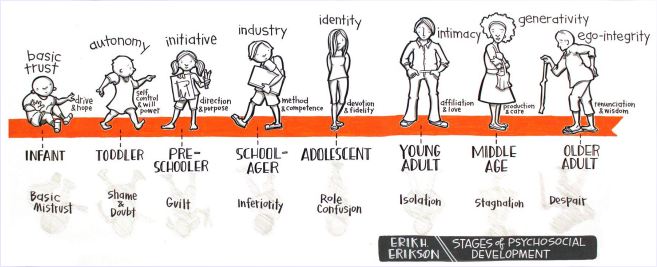
TABLE 4.1

PIAGET'S STAGES OF COGNITIVE DEVELOPMENT

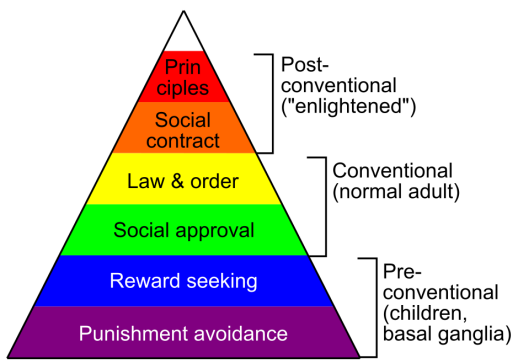
Typical Age Range	Description of Stage	Developmental Phenomena
Birth to nearly 2 years	*Sensorimotor* Experiencing the world through senses and actions (looking, touching, mouthing, and grasping)	• Object permanence • Stranger anxiety
2 to about 6 or 7 years	*Preoperational* Representing things with words and images; use intuitive rather than logical reasoning	• Pretend play • Egocentrism • Language development
About 7 to 11 years	*Concrete operational* Thinking logically about concrete events; grasping concrete analogies and performing arithmetical operations	• Conservation • Mathematical transformations
About 12 through adulthood	*Formal operational* Abstract reasoning	• Abstract logic • Potential for mature moral reasoning

No actual stages.. But useful simplification

Erikson Psychosocial Development



Kohlberg's moral stages



Moral Development
(basic drives to make society work)

Haidt:

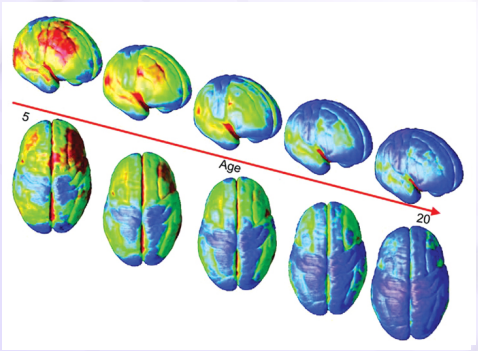
- Care / harm: like reward / punishment – basic
- Fairness / justice: no cheaters! Or cheated!
- Group Loyalty: love the in-group, hate the out-group
- Respect for authority: stay in line!
- Purity and sanctity: rules about sex, food, nudity, etc

How Does it Work?

Problem: Truly understanding development requires truly understanding how it all works!
(absurd to teach 1 lecture on this topic!)

- Brain maturation?
- Learning?
- Schema assimilation, accommodation? (Piaget)
- Internal drives?
- External forces (social, parental), schooling?

Brain Maturation: Synaptic Pruning



Blue = thinner = more synapses pruned = more mature
Sensory areas mature first, then "higher level" areas; PFC last of all

Early Sensory/Motor Learning

First 6 months: learning to predict what you'll see next – passive sensory learning about basic physics, object permanence, object shapes, etc

- CCC = Compression, Contrast
- We have initial computer models of this
- E.g.: Objects are solid, Objects only move through contact, Objects travel through space in continuous path.. Spelke et al: Nativism (built-in) vs. learned..
- Physics = a "schema"?

Early Sensory/Motor Learning

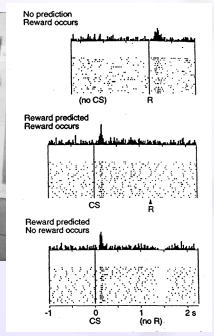
Then: more active motor grasping and manipulation – starting to learn about self-efficacy

- Learning that we can affect the world, prelude to full sense of agency..

How Much of Learning is Passive?

Pavlov

Skinner



Dopamine

At 2 Years of Age, a Miracle Occurs

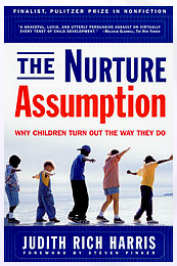
Tantrums!!!

Human Learning is Active! CCC = Control!

- Kids carefully decide what to try or avoid
- Boredom and curiosity drive expansion of abilities over time
- Social influences are major: kids especially sensitive to peers – we are herd animals!

The Nurture Assumption

- Very little evidence of parental influence on children, *beyond genetics*
  - Genetic / environment correlation?
- Peers matter the most of environmental influences
  - Which language to immigrants learn?
  - Who did you talk most w/ in High School?
- What data tells us these things?



Extreme Cases

Parents only don't matter if they're 'normal' (and actually present)

- Romanian orphans
- Abuse, neglect, etc
- (Same point about genetics dominating when there isn't too much variance in the environment: how different *really* are different parents?)

Temperament: Personality vs Big 5 OCEAN

Effortful *control:* Conscientiousness

Negative emotionality: Neuroticism / not-Agreeableness

- "avoid" dimension

Extraversion: Extraversion / Openness

- "approach" dimension

Basic "parameters" on motivational system..

Attachment Theory

Nice metaphor, but likely largely bogus..

We don't see entire world through lens of *mother* (how many others fit the *mother* role??)

Strange Situation and Attachment Styles:

- **Secure**: Need mommy, miss mommy, all good with strangers as long as mommy is around..
- **Avoidant**: Disengaged, even from mommy..
- **Insecure-Ambivalent**: Wary, anxious, mad at mommy..

Beyond *Boyhood*

- Adolescence: Everything in place except good judgment! And an appreciation of it all..
  - youth is wasted on the young
- Young adult: what do I do with my life?
- Adult: joys of parenting, marriage
- Midlife: did someone say crisis?
- Golden years: and then you die..

Development Summary

- Brain maturation = synaptic pruning, goes from sensorimotor up to higher areas (prefrontal cortex is last = Control area)
- Overall Stages: Sensorimotor, preoperational, concrete operations, formal operations
- Temperament: reasonably stable, effortful control, negative affect (avoid), extroversion (approach)
- Attachment: secure, avoidant, insecure/ambivalent: reflects personality vs. shapes it? (Reflects!)
- Adolescents: lack PFC for making good decisions..

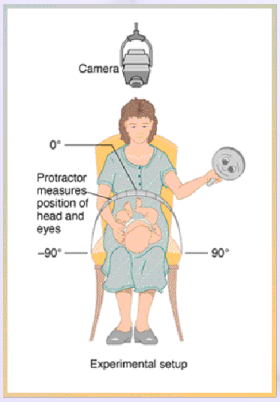
Research Methods

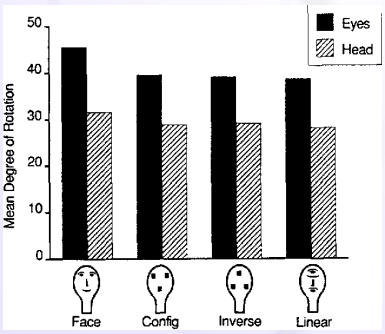
It is especially challenging to figure out what preverbal, jello-ball babies are thinking!

- they can't talk, point, push buttons..

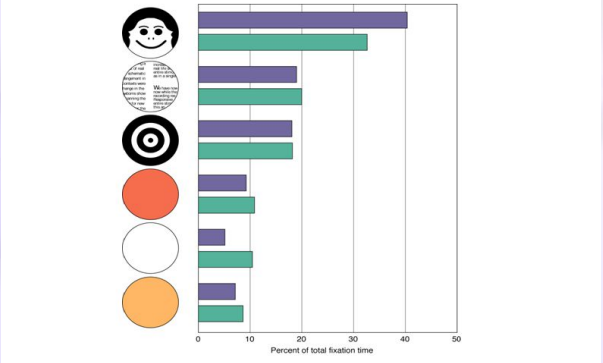
How would you do it? Hint: have you seen *The Theory of Everything*?

Visual Tracking

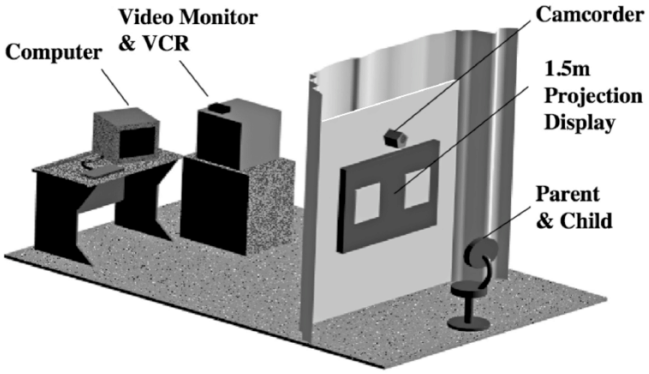




Infants Prefer Visual Patterns



Preferential Looking: Habituation



Object Permanence