Are we still evolving?

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Conventional wisdom

Something must have happened to weaken the selective pressure drastically. We cannot escape the conclusion that man's evolution towards manness suddenly came to a halt.

—Ernst Mayr 1963

Natural selection has almost become irrelevant in human evolution. There's been no biological change in humans in 40,000 or 50,000 years. Everything we call culture and civilization we've built with the same body and brain.

—Stephen Jay Gould 2000

Certainly, human nature is fixed. It's universal and unchanging —common to every baby that's born, down through the history of our species.

—Helena Cronin. 2000 Getting Human Nature Right.

If humans had been evolving lately, how would we know?

How can recent selection be detected?
Let's examine some human DNA.

Look at some DNA sequence data

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Ref   T G C A T G T A A T G C T
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A       . . . . A . . . . G A A .
B       . . . . A . . . . G A . .
C       . . . . . T . G . . . . C
D     C . . . . . . G G . . . C
E     C C . . . . . G G . . . C
F     C . . . . . C G . . . . C
G     C . T . . . C G . . . . C
H     C . T G . . C G . . . . C
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    (Garrigan et al 2004)
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- A–H: human DNA sequences
- Dots mean identical to chimp.
- Note similarity between A and B.
- Called "linkage disequilibrium" (LD)
- Natural selection generates LD.

What happens when a favorable mutation strikes some lucky chromosome?

- Better-than-average chance of spreading through population.
- What is it that spreads?
  - The entire chromosome?
  - Just the mutated nucleotide site?

Neither: the answer is in between.

Cross-overs shuffle DNA
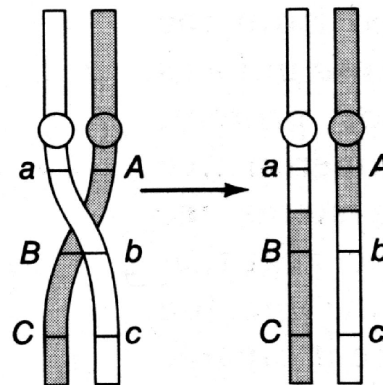
- occur during reproduction.
- shuffle parental chromosomes.
- sites far apart shuffled more.
- result: "recombinant" chromosomes

The chromosome you pass on to your child

- Not like either of those you inherited from Mom or Dad.
- A mosaic, made of pieces of Mom's and Dad's.
- Technical terms: *recombination*, *recombinant chromosomes*

What happens to lucky chromosome?

- Favorable mutation surrounded by region from original chromosome.
- Recombination gradually reduces size of that region.
- The older the mutation, the smaller the region.
- Technical term: *linkage disequilibrium* (LD)

How a selective sweep generates LD
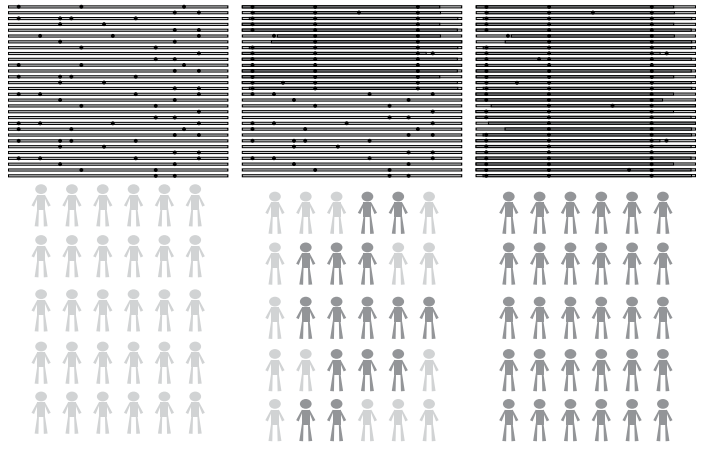
Common neutral mutations

- May accidentally drift to high frequency, but this takes a long time.
- Plenty of time for recombination.
- Sit on *short* stretches of original chromosome.

Common favorable mutations

- Increase rapidly in frequency
- Little time for recombination.
- Sit on *long* stretches of original chromosome.

DNA sequences from region of human lactase gene

```
       cgcttcaggcattcctatctaaacagaccaacgtaAgggtacaatgcctaacccagacgtttcaactct
20     ....................................................................
21     ....................................................................
22     ....................................................................
23     ....................................................................
24     ....................................................................
25     ....................................................................
26     ....................................................................
27     ..................t.................................................
28     ..................t.................................................
29     .....................................................c..............
37     ...............................G..a.gt....t........gac.c.tgtct.
38     ...ccgga....gat..at..gg..c.....tc.gGaaa.g..ccttt...tg......c...t.t...
39     ...ccgga....gat..at..gg..c.....tc.gGaaa.g..ccttt...tg......c...t.t...
40     ..tcc...agtag.t.cat..g.....t..ttccgG..a.gt.....t........gac.c.tgtct.
41     ..tcc...agtag.t.cat..g.....t.gttccgG..a.gt.....t........gac.c.tgtct.
42     ..tcc...agtag.t.cat..g.....t.gttccgG..a.gt.....t........gac.c.tgtct.
43     ..tcc...agtag.t.cat..g.....t.g.tc.gG..a.gt.....t........gac.c.tgtct.
44     ..tcc...agtag.t.cat..g.....t..ttc.gG..acgt.....t........gac.c.tgtct.
45     ..tcc...agtag.t.cat..g.....t.gttc.gG..a.gt.....t........gac.c.tgtct.
46     ...ccgga....gat..at..gg..c.....tc.gGaaa.g..ccttt...tg......cg.gt.t..c
47     ..tcc...agtag.t.cat..g.....t.gttccgG..a.gt.....t........gac.c.tgtct.
48     ..tcc...agtag.t.cat..g.....t.gttccgG..a.gt.....t........gac.c.tgtct.
49     ..tcc...agtag.t.cat..g.....t.gttccgG..a.gt.....t........gac.c.tgtct.
50     tatccgga....g.tc.atcgg.tc.g.tg.tc.gG..a.g.g....tg....ggt...cg.gt.t..c
51     ta.ccgga....g.t..atcgg.tc.g.tg.tc.gG..a.g.g....tg....ggt...cg.gt.t..c
52     ta.ccgga....g.t..atc.g.tc.g.tg.tc.gG..a.g.g....tg....ggt...cg.gt.t..c
53     ta.ccgga....g.t..atcgg.tc.g.tg.tc.gG..a.g.g....tg....ggt...cg.gt.t..c
```

Evidence for natural selection at lactase gene

- ▶ Lucky chromosomes nearly identical.
- ▶ Unlucky chromosomes vary.
- ▶ Region of LD covers nearly a million nucleotides in European population.
- ▶ Absent in Africa and Asia.

LD on human chromosome 2 (Voigt et al 2006)

What evolutionary changes might we expect?
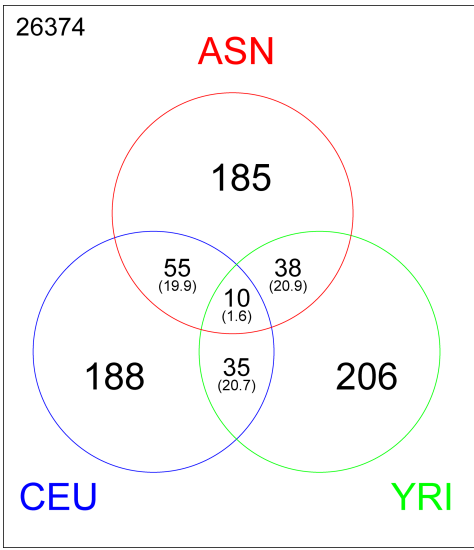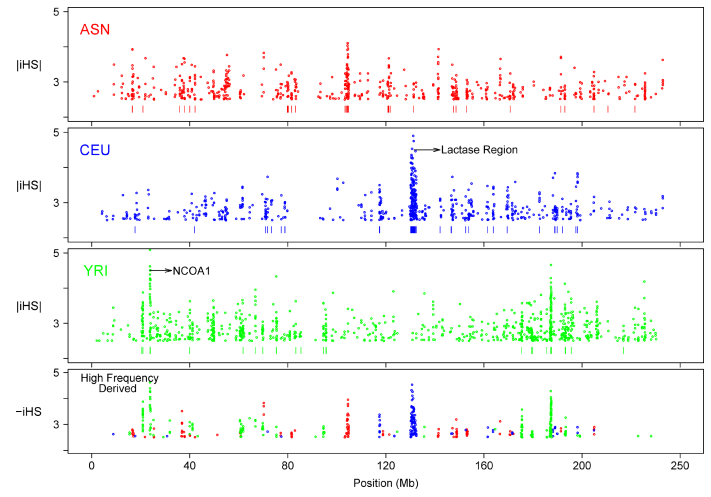
Voight et al (2006): 431 sweeping loci.

ASN: Asia
YRI: Africa
CEU: Europe.

Most are sweeping w/i only one continent.

| Cause	$\longrightarrow$ Expected response
diet	$\longrightarrow$ metabolism (protein, carbs, etc)
longevity	$\longrightarrow$ DNA repair
intelligence	$\longrightarrow$ neural function
population density	$\longrightarrow$ immune response

GO Nesting	GO Category	ASN	CEU	YRI
21–1	Chemosensory perception	–	0.0006	0.0004
21–1–1	Olfaction	–	0.0006	0.0008
22–2	Gametogenesis	0.008	–	–
22–2–2	Spermatogenesis and motility	0.02	0.03	–
22–3	Fertilization	0.004	0.003	–
1–11	Other carbohydrate metabolism	**0.0002**	–	–
6	Electron transport	–	**0.0002**	–
4–13	Chromatin packaging/remodeling	<**0.0001**	0.01	–
16–1–1	MHC-I–mediated immunity	–	<**0.0001**	0.02
3–2	Steroid metabolism	–	–	<**0.0001**
3–5	Lipid and fatty acid binding	0.001	–	–
4–4–2	mRNA transcription initiation	–	0.002	–
5–3	Protein modification	0.002	–	–
7–5	Vitamin/cofactor transport	0.002	–	–
9	Phosphate metabolism	0.002	0.03	–
13–4	Peroxisome transport	–	–	0.002

All *p*-values are one-sided, testing for enrichment of categories in each population; "–" indicates that the *p*-value is >0.05.

Recent Acceleration in Rate of Evolution (Hawks et al, 2007)
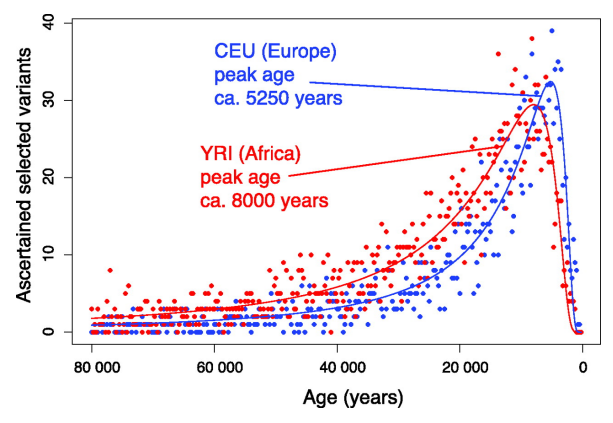
Why the recent burst of evolution?

Hawks et al (2007) argue that we have changed our own environment:

- population size
- agriculture
- complex society
- long-distance trade

To say nothing of the more recent changes.

Summary

- Recent positive selection on many human genes.
- Favored alleles originated within past 40 kyr.
- A burst of adaptive evolution.
- Several functional categories.
- Suggests responses to increased population size, to shifts in diet, and to longevity.