

## Human Evolution

modern humans are a relatively new species on the planet

oldest **Homo sapiens** fossil are ~200,000 yrs old

about 100 B people have lived on earth so far or about 100,000 generations

today we can trace human history using the males' "**Y-chromosome**" and **mitochondrial DNA**

the Y chromosome is passed to the males of every generation

DNA in the mitochondria and passed the males & females of every generation

One misconception surrounding mitochondrial Eve is that since all women alive today descended in a direct unbroken female line from her, she must have been the only woman alive at the time. However, nuclear DNA studies indicate that the size of the ancient human population never dropped below tens of thousands. Other women living during Eve's time have descendants alive today, but at some point in the past each of their lines of descent did not produce a female, thereby breaking the mitochondrial DNA lines of descent.

results of **mitochondrial** genetic studies indicate that all living humans are related to a single woman ("Eve") who lived ~150,000 years ago in east Africa

results of **Y-chromosomal** inheritance studies indicate that all living humans are related to a

single man ("Adam") who lived sometime between 120,000 to 156,000 years ago

however, some Cameroonians and one African American tested have Y chromosomes not related to the above male ancestor; their Y-chromosome date to between 180,000 to 581,000 years ago

the human genome is 99.9% identical worldwide

the human genome is also ~98% the same as the genome of chimps (our closest living relatives)

→ how did we get to that point?

### Primates

humans are in the order **Primates** and evolved from some early member of this group

earliest primates appeared ~65 MY ago during time of great diversification of mammal after the extinction of the dinosaurs

**primates** lived in trees (= arboreal) which selected for a specific group of traits important in human evolution:

- a. 5 digits sometimes with opposable thumb  
→ better gripping and dexterity
- b. nails rather than claws

→ greater tactile sensitivity of fingertips

#### c. visual acuity

could form sharp images  
had color vision  
decreasing reliance on chemical senses

#### d. greater maternal care

longer, stronger mother-child relationships

#### e. tendency toward upright posture

at least could sit upright

### Hominidae

**primates** are divided into 13 "families" which include the gibbons, marmosets, old world monkeys, tailed monkeys and the **Hominidae** which include the "great apes": gorillas, chimps and us.

used to be "the family of man" more recent genetic analysis showed it should also include closely related primates

apes first appeared ~20 million years ago (miocene)

a time when woodland savannas were replacing forests and spreading across Africa, Europe and N. America

earliest fossils were smaller than a chimp

tended toward bipedalism

more use of hands and arms for manipulation

may have moved to grasslands early

→ seems to have eaten roots and seeds rather than soft vegetation of plants

### modern Apes & Chimps

most are larger than other monkeys  
larger brain in proportion to size  
long arms & short legs → brachiation

4 modern genera  
eg. gorillas, chimps

### Humans and Human Ancestors (Hominins)

#### uniquely "human" traits

– not found in other living primates:

- a. habitually erect posture → truly bipedal
- b. lower limbs longer than forelimbs
- c. non-opposable larger toes
- d. reduced canines
- e. bony chin
- f. prominent nose
- g. relatively hairless
- h. much larger brain led to:  
→ abstract thinking  
→ speech and language  
→ use of complex implements

- belief in supernatural and life after death
- importance of cultural evolution

the evolutionary branch leading to humans probably began ~7 million years ago

molecular evidence indicates that Great Apes diverged from human line ~10 MY ago (DNA is ~97% similar)

chimps diverged ~8 MY ago (DNA is ~98% similar)

it apparently wasn't a clean break

- both ancestral lines apparently continued to interbreed for ~1.2 MY after the split (based on DNA analysis)
  - chimps share 98% of our genes
  - 40 million molecular changes from them to us only 250,000 seem most responsible for the physical and mental differences between us and them (AAS 9-1-05)

the earliest fossils of human ancestors appear in the fossil record ~4.4 Million years ago

### 1. *Ardipithecus ramidus* ("Ardi") [4.4 MY]

lived in the woodlands of E Africa  
 ~4' tall, weighed ~110 lbs  
 had long arms, short legs with opposable toes  
 spent most of their time in trees; ate, slept and raised young in trees  
 but could easily walk on 2 legs and carry food in arms, cruised the trees on all 4's  
 probably several distinct species of the genus

*Ardipithecus* was probably in direct line of descent to us

if so, they are separated from us today by over 300,000 generations

### 2. *Australopithecus sp.* [4.2 – 2.3 MY ago]

several species known (eg. "Lucy" & Taung Child);

some not in our direct line of ancestry

4' tall, ~50 lbs

the first bipedal primate (the only one of the time)

walked upright (bipedal), ground walker

lived in open grasslands (eg. Lucy & footprints)

→ better vision in grasslands

→ frees hands for weapons and harvesting

still had relatively long arms

still probably spent lots of times in trees

no dramatic increase in brain size;

slightly larger brain than modern monkeys and apes (relative to size)

relatively small canines and incisors compared to apes

some species began using primitive **tools**

improving tool use in human line probably led to the development of speech

making tools uses the same areas of the brain as speech

during this time our ancestors acquired one of today's uniquely human parasites, pubic lice

genetic analysis indicates the pubic lice evolved from gorilla body lice about 3 M years ago

this also indicates that our ancestors of the time may have spent considerable time with gorillas then

abt 2.5 MY ago *Australopithecus* split into 2-3 major evolutionary lines:

*A. robustus*, *A. boisei* & ***Homo habilis***

### 3. *Homo habilis* [2.5 – 1.6 MY]

earliest "human" fossils (same genus as us)

existed same time as *Australopithecus* and shares many of same traits with following changes:

- more delicately built
- females ~ 1/2 as large as males
- males probably had harems as do apes

→ tooth size decreased

diet changed from largely vegetarian to more carnivorous

### → large increase in relative brain size

higher protein diet fed brain development

brain uses 20x's more energy than muscle

→ larger brain needed more high quality food

at exactly this time when our genus (*Homo*) first appears, fossil and genetic evidence indicates that:

→ a single gene was duplicated that gave brain cells (neurons) the ability to form more complex shapes and connections allowing the exchange of more information with a larger number of neighboring cells

→ Infant skulls became more flexible allowing them to accommodate larger brains

*H. habilis* was also a tool user

### 4. *Homo erectus* (eg. Peking Man) [1.8 MY – 30,000 yrs ago]

the fossil called *H. habilis* is so similar to *Australopithecus* that it is questioned by some to not actually be in our genus at all

by 1.5 MY a group of hominins had evolved that are indisputably in our genus

distinctly different from *Australopithecus* and much more similar to us:

- skeleton similar to ours
- close to our size, ~5' tall, ~100 lbs;
- males and females similar sizes
- similar stride

more efficient walk than *Australopithecus*

wider ranging than *Australopithecus*

- first hominids to migrate out of Africa
- fossils found in Africa, Asia & Europe

the main difference between *H. erectus* and us is the skull

- their skull is thick and massive
- large jaws and teeth, no chin

**show another dramatic increase in brain size**

- brain size is correlated with intelligence
- it evolved 100's of x's more quickly than most traits evolve
- this occurred *after* bipedalism and tool use
- strong selective pressure for brain development

were efficient hunters

earliest use of projectile weapons

plenty of game, more grasslands in their time

killed elephants, rhinos, antelopes, bears, hippos and giant babboons

sometimes stampeded them into marshes or over cliffs

new analyses indicate that the the anatomy and physiology of humans became **adapted toward distance running** and **spear throwing** about 2 M years ago

running was perhaps an adaptation for hunting

running prey to exhaustion

a well conditioned human can run 5 miles or more

as good as wild dogs, zebras, anteloes and wildebeasts

it would also allow us to compete with dogs and hyenas for widely dispersed carcasses

humans are the only primates who **can launch a spear or rock** overhand with speed, force, and precision

all other primates throw underarm with poor aim

**1<sup>st</sup> ancestor to tame fire; all before "ran from it"**

before fire use early hominins ate tough, raw foods that required lots of chewing and digesting to break food down

- cooking made all foods more easily digestible
- more nutrition for less effort
- enhanced brain development
- teeth got smaller

≥1.2 MY ago: genetic evidence indicates ancestral "fur" was shed; we became "naked apes"

a naked body allowed us to sweat to keep cooler in a warm environment

fewer fleas and other ectoparasites

*H. erectus* probably had limited speech ability

fossil evidence suggests that areas of the brain responsible for language existed over 500,000 years ago

spoken language developed before written language

### 5. *Homo neanderthalensis* [600,000 – 30,000]

(Neanderthal man)

mainly in Europe and near east; earliest fossils from England and Germany

more heavily built, very strong

protruding face, low skull, heavy brow

brain size equivalent to ours

had language

communication and culture became more important than physical evolution

used tools

cared for invalids

buried their dead with weapons, food & flowers

→ belief in afterlife

lived with *H. sapiens* (us) for over 100,000 years

occasionally interacted with us

even bred with us a few times

### 6. *Homo floresiensis* (the "hobbit") [95,000 - 13,000]

recently discovered in a cave on a remote island in Indonesia

lived with pygmy elephants & Komodo dragons

may have evolved as separate line from *H. erectus*

~ 3.3' tall, weighed ~55 lbs

upright, bipedal, large feet!

longer arms than modern humans

small brained  
used fire and made tools  
hunted large game → required communication and planning  
modern humans didn't reach the island until ~11,000 years ago so we don't think the hobbits interacted with modern humans

## 7. *Homo sapiens* (Cro Magnons) [200,000 – present]

our species apparently first appeared ~200,000 years ago

*H. erectus*, *H. neanderthalensis*, *H. floresiensis* & *H. sapiens* and possibly 1 or 2 more species coexisted for 1000's of years

*H. erectus* & neanderthals disappeared abruptly about 34,000 yrs ago

replaced by Cro Magnon (except *H. floresiensis*)

physically indistinguishable from us

less massively built than Neanderthals

made far better tools: knives, awls, chisels, engravers, etc

could make spears, harpoons, fishhooks, needles

170,000 yrs ago: humans and our "cousins" began wearing **clothing**

→most recent analysis indicted by genetic evidence for evolution of human body louse species that only lives in clothing, not on skin or fur from human head louse. a reanalysis indicates it might have been much earlier

~100,000 years ago earliest known use of jewelry and cosmetics

~60,000 yrs ago earliest needles appear

indicating that people had begun to sew and create clothing

~35,000 yrs ago: earliest cave paintings

~60,000 years ago perhaps ~1000 people moved out of Africa and into western Asia

(some evidence indicates that humans first left Africa ~120,000 yrs ago but this group quickly died out and left no descendants)

ancestors of this group eventually replaced all earlier kinds of humans including the neanderthals

all "non-Africans" are descendants of this small band

they reached Australia ~50,000 years ago where they became genetically isolated from other humans and became the aborigines

~40,000 years ago humans pushed to central Asia and to Japan and Siberia

genetic evidence suggests that humans moved into the Americas 20,000-15,000 years ago

during this time groups in some areas became relatively isolated as agriculture and village life caused our species to become more settled

→ genetic differences between races arose during this time

eg. black skin evolved as protection against UV radiation of sun in warm tropical areas

[Biologically speaking, **Race** is a genetically distinct variation within a particular species of animal or plant. What we consider "racial differences" among humans do not fit this criterion; genetically the differences between human races are not significantly different from the genetic variation among individuals]

by end of Paleolithic (~10,000BCE):

→only a few places had not yet been settled by humans

→human population was ~ 600,000,000

## **Social Evolution**

after *Homo sapiens* emerged about 200,000 years earlier, it took another 140,000 years before any sign of modern civilisation emerged

up until this time biological factors controlled our evolutionary development

about 65,000 years ago the biological structure of our brain stopped changing

we began to interact more as groups; families, clans, villages

human interactions allowed us to learn and do things we could not do alone

we could teach these things to our kids; pass on our knowledge

very few examples of this in other primates and other animals

from then on 'social evolution' superseded biological evolution in learning to interact with the world and solve problems

## **Agricultural Revolution** (10,000BCE)

a pivotal moment in our social development came with the agricultural revolution

led to a more settled existence

less time spent on survival

more time spent on higher brain functions

### Some Milestones in Human Biological & Cultural Evolution

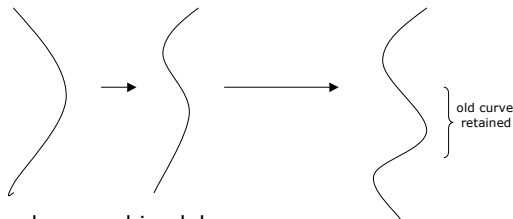
- 65 MY ago: earliest primates appear (diversification after dinosaur extinctions)
- 20 MY ago: earliest examples of Hominidae (great apes)
- 7 MY ago: beginning of Hominid line that lead to us
- 4.4 MY ago: earliest fossils of this line ("Ardi")
- 4.2 MY ago: first bipedal primate *Australopithecus*
- 2.5 MY ago: *Homo habilis*; earliest fossils of genus *Homo*
- 1.8 MY ago: first stone projectile weapons
- 1.5 MY ago: *Homo erectus*; dramatic increase in brain size, 1<sup>st</sup> migration out of Africa
- 1.2 MY ago: shed fur to become "naked ape"
- 1 MY ago: first evidence of controlled fire use
- 600,000 yrs ago: first neanderthals, a very closely related european species - could even interbreed with *H. sapiens* that appeared later
- 500,000 yrs ago: first evidence of construction of shelters
- 200,000 yr ago: first modern humans, *Homo sapiens*, appear
- 140,000 yrs ago: earliest evidence of long-distance trading
- 100,000 yrs ago: earliest known use of jewelry, body paint and water containers
- 72,000 yrs ago: humans began wearing clothes – probably animal skins
- 60,000 yrs ago: oldest known needle – animal skins gave way to manufactured clothing
- 60,000 yrs ago: second migration out of Africa: all non-africans are descendants of this small group
- 50,000 yrs ago: oldest indication of ritualistic burial
- 35,000 yrs ago: oldest cave art
- 20,000 yrs ago: "racial" differences evolved as small groups of humans became more isolated and more settled
- 10,000 yrs ago: origin of agriculture, 1<sup>st</sup> known lunar calendar; the entire human population was about 600,000,000
- 8,000 yrs ago: plough invented
- 5,000 yrs ago: earliest writing, simple sewage systems to dispose of wastewater
- 2,600 yrs ago: oldest written legal code
- 2,300 yrs ago: birth of science (Aristotle)
- 250 yrs ago: the Industrial Revolution began
- 450 yrs ago: origin of the germ theory of disease

## The Scars of Human Evolution

### Bipedalism

various evolutionary changes, esp bipedalism, resulted in a "terrific mechanical imbalance" in body

we are born with a backbone that has the ancestral curve of a 4 legged creature



as we become bipedal

1. stress points shifted from more evenly distributed 4 legged posture
2. vertebrae had to become more moveable to facilitate all these new curves  
→ weakens the back → sore back
3. the whole pelvis was tilted upward  
→ narrow birth canal
4. rather than viscera hanging evenly and weight

distributed along all of vertebral column  
all organs are piled on top of each other  
→ hernias

5. the weight of our upper body is borne by pelvis and its junction with vertebral column =sacroiliac  
→ lower back pain
6. also, wider distance between rib cage and pelvis  
→ less protection for lower abdominal organs
7. also, harder to pump blood from feet back up to the heart which is 4 ft off ground  
→ varicose veins, hemorrhoids
8. much bigger burden on our feet  
→ fallen arches  
bunions  
callouses

### Head

humans are the only living animals that are habitually bipedal

head is balanced on top of vertebral column  
foramen magnum moved to inferior location

face became flatter

don't need strong neck muscles as does a 4 footed animal → brow ridges became small

### Brain

1. in skull, brain case has expanded greatly  
→ larger face, smaller snout
2. while face bones have decreased in size  
our teeth have remained large  
→ impacted wisdom teeth
3. big head, small birth canal  
→ difficult & painful births

## Relics of Human Evolution

eg. birds lost their teeth 70 million years ago but still have the gene to produce them

### 1. The Appendix

in plant-eating vertebrates the appendix is large and contains lots of microorganisms to help in the digestion of food

modern humans eat mostly meat and no longer have a need for such structure

### 2. Wisdom Teeth

as our face lost its snout the mouth had less room for teeth

however there may have been an early advantage since our early ancestors probably frequently lost jaw teeth and the wisdom teeth would serve as useful replacements

### 3. Tailbone

small fused vertebrae are only a vestige of the tail of our primate ancestors.

Occasionally today a baby is born with a tail

there are > 100 medical reports of babies born with tails, sometimes tiny vestigial structures, some have vertebrae and can even move

If that had happened in the dark ages the child and his mom would have been burned as witches

### 4. Extrinsic ear muscles

three muscles allowed ancestors to move ears as in dogs and rabbits.

we still have them and some learn to use them

### 5. Arrector Pili Muscles

small bands of muscles attached to our hair follicles

in other mammals it helps them to fluff up their fur against the cold

in humans, who have shed most of their fur, they just cause goose bumps

## Atavisms

less clear possible remnants of human evolution

### 1. large canines (possibly)

some have large canines  
Darwin viewed them as an atavism  
fossil evidence indicates that our canines began shrinking as soon as we diverged from chimp ancestors

### 2. extra nipples or breasts (yes when on milkline)

most mammal have multiple pairs of nipples  
most primates have only 1 pair  
1 in 20 people have at least 1 extra nipple  
they usually occur along the "milk lines"

### 3. hand walking (no)

five Turkish siblings walk on all 4's  
gait resembled apes  
not an atavism; is brain damage affecting their balance

### 4. undeveloped thumb (unclear)

some are born with short thumbs lacking some of the usual muscles  
a few also have long slender fingers  
in some it leads to lack of fully opposable thumb

### 5. lack of sweat glands (probably not)

some people lack sweat glands  
but most cases seem to involved mutations that block sweat gland formation altogether whereas in apes there are sweat glands ins the palms and soles

### 6. polydactyly (probably)

extra fingers or toes are one of the most common

congenital defects in humans and other animals seems to be controlled by two genes during development

### 7. **syndactyly** (yes)

webbed fingers or toes are a common birth defect probably the result of the self destruct mechanism being disrupted to cells between are not destroyed development is very similar to development of fish fins except for the destruction of the web later in development

### 8. **Branchial cleft cyst** (perhaps)

in 4th week of development vertebrate embryos develop five ridges in the neck region in fish, these ridges go on to form gills in humans they form various structures in head or neck the clefts between ridges normally disappear but sometimes a fluid filled sac called a branchial cleft cyst remains

### 9. **twinning** (unclear)

some think it's a throwback to large litters of our early mammalian ancestors some women have tendency to have nonidentical twins

### 10. **hiccups** (perhaps)

may be a primitive reflex inherited from our land conquering ancestors these primitive air breathers had both gills and lungs the pattern of muscle movements in hiccups resemble those seen when such animals close their glottis to stop water getting into the lungs and contract the mouth cavity to pump water over the gills

### 11. **various muscles** that were once useful in our quadrupedal ancestors and are greatly reduced or absent in many humans today:

**subclavius muscle** – small muscle stretching from rib to collar bone would have been more useful if we walked on all 4's. Missing in some people

**palmaris muscle** – long narrow muscle from elbow to wrist may once have been important in hanging and climbing. Today is missing in 11% of humans

**plantaris muscle** – useful for other primates for grasping with their feet. Today missing in 9% of the population

### 12. **5<sup>th</sup> toe**

apes use all their toes for grasping or clinging to branches. Humans use mainly the big toe for balance. The smallest toe is almost nonfunctional now

### 13. **The thirteenth rib**

chimps and gorillas have an extra set of ribs. 8% of adults have this extra set but most of us have only 12 pairs

### 14. **Paranasal sinuses**

the sinuses of our early ancestors were lined with odor receptors that gave a heightened sense of smell. Humans have retained these sinuses but lost the smell receptors that lined them

## **Do Humans Continue to Evolve?**

evolutionary changes in the past 100,000 yrs have been minor

eg jaws, teeth, size, toes, etc

the brain and other major things remain essentially unchanged

structurally, the human form is **generalist**

= highly adaptable

the most dramatic structural changes in past 10,000 years are mainly due to better nutrition and health

humans are not dependent solely on physical structure for adaptability anymore

→ we are **tool users** and **social animals**

our tools have evolved greatly in the past few 1000 yrs

→ tools are an extension of us

"the speed of man's development is equal to the speed with which new tools can be invented and made"  
-Lewis (Man & Evol)

also, our social structure is an outgrowth of

technological development

language, knowledge, culture exist outside of the physical body

tools and society are subjected to different evolutionary processes

New (2007) research on the human genome indicates that, genetically, humans are evolving 30-40x's faster today than 40,000 years ago.

in terms of physical changes

→ those who say humans are no longer evolving sometimes confuse **evolution** with **speciation**

**evolution** is a change in gene frequencies over time

**speciation** occurs when there is so much change that members of the new gene pool can no longer interbreed with the original gene pool

the human gene pool is always changing  
→ it will never "stagnate"

but there may never be a new human species

→ this would require isolation of a population

humans haven't really changed the rules of Natural Selection

→ we are as much a product of evolution as any other organism

culture and technology might change the kinds of genes in the human gene pool but they cannot remove the force of evolution

we can now measure evolution at the molecular scale:

eg. new evidence suggests that two key brain-building genes which were critical in evolution to modern humans are still evolving and spreading rapidly throughout the human population

dramatic changes in the past coincided with huge leaps in human intellectual development

not everyone has these genes but the genes are increasing in the human population

one gene, **microcephalin**, began its spread among human ancestors about 37,000 years ago

→ a period marked by a creative explosion in music, art, religious expression and tool making

the other gene, **ASPM**, arose only about 5,800 yrs ago

→ about the time of emergence of major civilizations in the mid east

### Is Man becoming less well adapted to nature?

the physical environment has become far less severe a selective factor than in any other animal

behavior is a strong selective pressure in the animal kingdom

ability to learn  
to overcome obstacles  
parental care and protection

this behavioral shift initiates new selective pressures:

1. we are constantly finding more genetic links to behaviors and psychological factors
2. the conquest of disease and mitigation of the effects of aging have achieved spectacular results

→ new medical procedures may prevent weeding out of physically defective humans

eg. genetic diseases

such things actually counteract natural selection

→ may produce an increase in deleterious phenotypes

"are we sowing the seeds of our own species' doom?"

while modern humans have largely mastered their environment

and communication and interactions are tending to normalize our gene pool

still ~50% of human race live in poor conditions, shortages of food & water, disease is common, poor health

→ still very subject to natural selection