

## 5. Sexual Dimorphism



ANBI 116 Evolution of Sex  
Pascal Gagneux

January 21, 2020

### Current sexual Dimorphism in primates

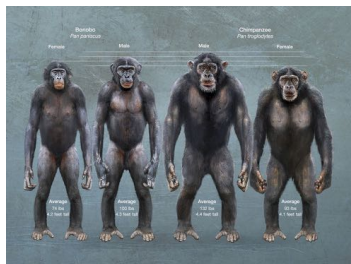


Four different primate species with striking sexual dimorphism: Asia: Proboscis monkeys, orangutans, Africa: mandrills, and Gorillas

Practice question: Name primate species with strong sexual dimorphism in Asia and Africa (two species each)

Asia “ Orangs and proboscis monkeys, Africa: Gorillas and Mandrills.

### Current sexual Dimorphism in primates



National Geographic

Our two closest living relatives Bonobos (also called pygmy chimpanzees) and chimpanzees (also called common chimpanzees) have strikingly different degrees of sexual polymorphism. The larger difference in body size seen in chimpanzees correlates with more male-male competition for access to females and with male dominance. Bonobos on the other hand are have female social dominance. Females of both species mate with many males during each ovulatory period, giving rise to high levels of sperm competition, thus explaining the huge size of testes and large sperm numbers in male ejaculates (10X that of human males).

Practice question: Which species has more pronounced sexual dimorphism, bonobos or chimpanzees?

Chimpanzees.

## Reconstructing past sexual Dimorphism

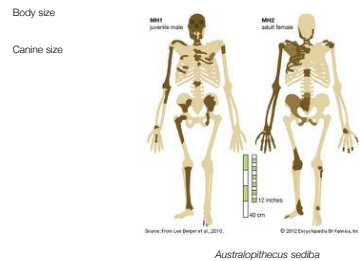


There is a lot of interest in reconstructing the appearance of extinct hominids (individuals of species belonging to any of the species that were ancestors to humans or closely related to those ancestors). Without large numbers of almost complete skeletons, this is very difficult to do. Neanderthals, a recently extinct species, are estimated to have had similar levels of sexual dimorphism in body size as modern humans.

Practice question: What mistakes could ignoring sexual dimorphism introduce in our interpretations of hominin fossils?

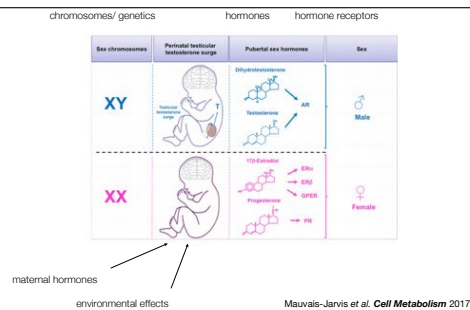
We could consider males and females from a strongly sexually dimorphic species as two different species.

## Reconstructing past sexual Dimorphism



The recently discovered Australopithecus sediba from a cave in South Africa provided a rare opportunity to estimate very modest sexual dimorphism in this 2 million year bipedal hominin, that was not a direct ancestor to modern humans, but rather an independent lineage.

## Origin of sex differences

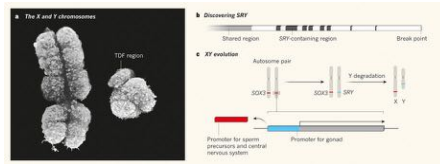


Sex differences in physiology begin during development from the combination of genetic and hormonal events and they continue after puberty. They result from the combination of the cell-autonomous effect of sex chromosomes, the organizational action (masculinization) of the testicular testosterone surge in males, and the activational effect of male and females sex hormones acting on their receptors after puberty. T, testosterone; AR, androgen receptor; ER, estrogen receptor; GPER, G-protein-coupled ER; PR, progesterone receptor. Steroid sex hormones are not encoded in genes, there are no genes for T or E, but rather synthesized from cholesterol in the diet. the receptors on the other hand are proteins encoded in our DNA.

Practice question: what class of biomolecules do sex hormones like estrogen and testosterone belong to?

## Origin of sex differences

testis-determining factor on Y-chromosome



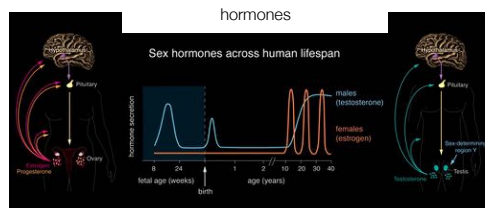
Marshall Graves J. *NATURE* 2015

In humans, sex is based on the presence or absence of the Y chromosome, seen here with its larger partner, X. The testis-determining factor (TDF) that drives male development was known to lie on the short arm of Y, but its identity was a mystery. b. In 1990, Sinclair et al. found two males with only a small piece of Y, which had been broken and fused to the X. They scoured the 35,000 base pairs between the break points and the region at the tip of the Y that is shared with the X, finding several regions (black) that were specific to the Y. One of these regions contained the TDF gene, SRY. c. This discovery led to an understanding of how X and Y evolved. The gene SOX3 was located on a pair of non-sex chromosomes (autosomes) in the ancestors of mammals. A promoter sequence drove expression of SOX3 in sperm precursors and the central nervous system. The promoter on one copy of SOX3 was replaced with a sequence that drives expression in the undifferentiated gonad (a tissue that can develop into either an ovary or a testis). This expression pattern allowed the new gene, SRY, to direct testis development. Over time, genes not needed for male development were degraded on this chromosome, giving rise to the Y.

Practice question: Do we know what kind of chromosome the Y chromosome of mammals originated from?

Yes, the X chromosome.

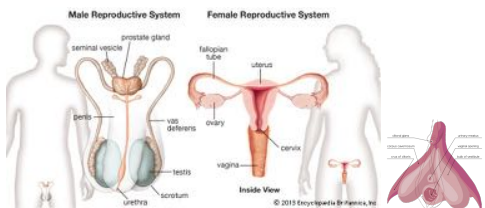
## Origin of sex differences



The time course and levels of sex hormones produced by the male and female body are strikingly different. These differences are already apparent in utero, during the development of the fetus. Males are exposed to a surge of T right after birth. In contrast to T, female estrogens are subject to strong monthly fluctuations after reaching sexual maturity. Cross talk between the brain and the gonads (testes or ovaries) is important in regulating levels of sex hormones.

Practice question: Name three periods in the development of a typical human male, when testosterone levels are elevated:  
fetal development, shortly after birth, after puberty.

## Sexual Dimorphism in Genitals



Anaxagoras: female is male turned outside in???

Male and female reproductive organs as shown in encyclopedia britannica

Tellingly, female breast are not considers reproductive, neither is the female clitoris indicates.....

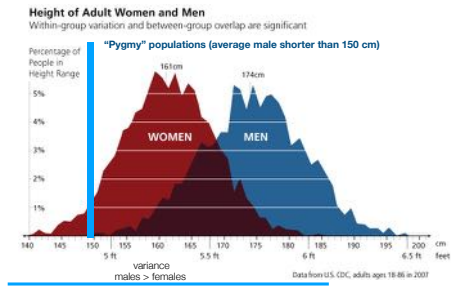
If anything, male organs are female turned inside out....

Genitals are massively sexually dimorphic, even though they developed from the same collection of fetal tissue. There are huge variation in the appearance and measurements of genitals.

Practice question: How can structures as different as female and male genitals originate fro the same primordial tissues?

Differential exposure to sex hormones activates different gene expression networks that direct the growth and development of tissues and structures.

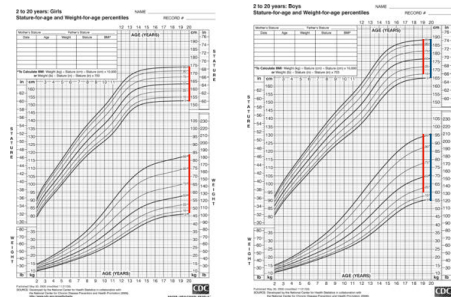
## Sexual Dimorphism in body size, height



One of the most apparent sexual dimorphism in humans is that in body height. As with many other dimorphism traits (measurable characteristics of an individual), there is substantial overlap. Another recurring theme is that the variance is larger in males than in females, i.e. males have individuals with more extreme traits very short and very tall....

Different means but widely overlapping variation in almost any female or male associated trait!!!!

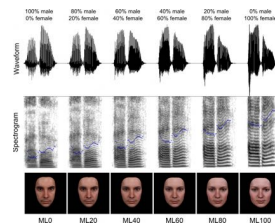
## Sexual Dimorphism growth pattern



The timing of development of girls and boys differs: girls reach their adult height (stature) and weight earlier, but boys catch up a few years later. Again, the variance in weight is larger for males.

Practice question: What does it mean that variance for many traits is larger in males?  
The extreme values measured are further from the mean.

## Sexual Dimorphism language and voice



Stuk, V. G., & Schweinberger, S. R. (2014). Influences of fundamental frequency, formant frequencies, asynchrony and spectrum level on the perception of voice gender. *Journal of Speech, Language, and Hearing Research*.

During puberty, the voice of males and females diverges, as males tend to grow longer vocal chords and develop their adams apple. Experiments show that the degree to which a voice is perceived as male or female, has an impact on perception by humans who hear the voice. (perhaps the deep "three testicle" voice used in many Hollywood movie trailers helps convince the public that the movie is worth watching...)

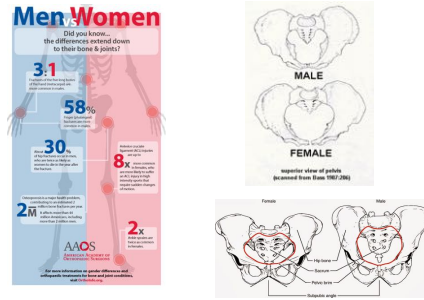
Practice question: What is one of the most sexually dimorphic aspects of human language?

Voice pitch.

also:

Earlier acquisition by females.

## Sexual Dimorphism in bone and joints



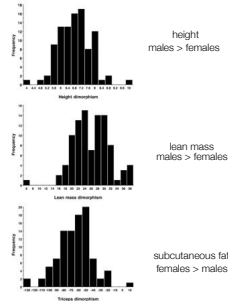
Sexual dimorphism in humans also exists in the skeleton and the joints. The pelvis and the Skull are often used by forensic scientists to identify the sex of human remains. the skull is more robust in males and the pelvis wider in females

## Sexual Dimorphism in body composition

### 96 non-industrialized populations

The magnitude of dimorphism was not randomly distributed across global regions, being lowest in African and Asian populations and greatest in Arctic populations.

Wells, J. C.K. (2012). Sexual dimorphism in body composition across human populations: Associations with climate and proxies for short- and long-term energy supply. *Am. J. Hum. Biol.*, 24, e11–e19.



A recent study of sexual dimorphism in 96 non-industrialized human populations reveals consistent (but variable degrees of) sexual dimorphism for stature, lean body mass and subcutaneous fat.

Practice question: Name a feature of body composition that women have more of than men.

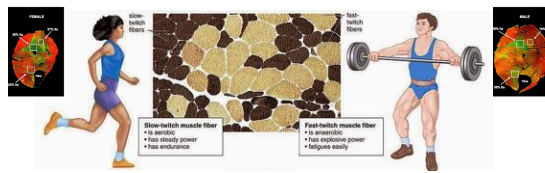
Subcutaneous fat.

## Sexual Dimorphism in muscle fibers

### muscle fiber type distribution



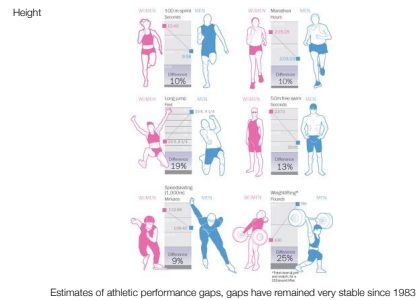
> 3000 genes are differentially expressed in male and female skeletal muscle



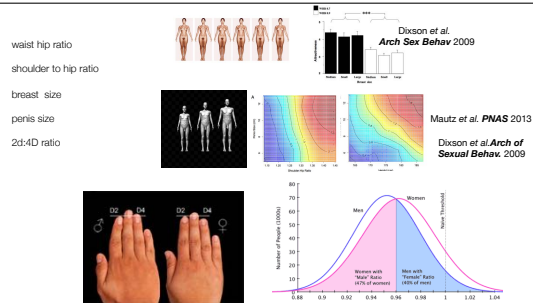
Haizlip et al., *Physiology* 2015

Female and males differ with regard to the composition of their muscles. Females have more slow twitch (fatigue resistant) and males more fast twitch (burst output) muscle fibers

## Sexual Dimorphism in athletic performance



## Sexual Dimorphism Body Shape



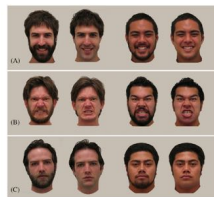
Body shape is also sexually dimorphic: females often have wider hips and a body shape characterized as hourglass, whereas males tend to have more narrow hips and wider shoulders. Again, there is much overlap between body shapes, but the distributions differ between males and females. The waist to hip ratio in females and the shoulder to hip ratio in males contribute to rating of sexual attraction. Female breasts are unique to humans, though female chimpanzees exhibit swollen breasts when lactating. Males across most cultures are influenced by female breast size when rating attractiveness of females. In Western societies where experiments have been conducted, females are strongly influenced by both male height and (flacid) penis size. A study in Cameroon found female preference of mid-range penis size.

Practice question: Name two features visible from a distance that are influencing male attractiveness to females in western populations.

Shoulder to hip ratio and height.

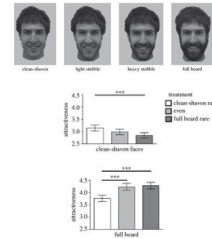
## Sexual Dimorphism in Facial Hair

### Dominance and Aggression



Dixon B and Vasey PL. *Behav. Ecol.* 2012  
BJ. 2014. Beards augment perceptions of men's age, social status, and aggressiveness, but not attractiveness

### Attractiveness



Janit ZJ, Brooks RC, Dixon BJ. 2014. Negative frequency-dependent preferences and variation in male facial hair *Biol. Lett.*

Male beards appear to contribute to perceived age, social status and aggression. They might also be under frequency dependent sexual selection. Beards become sexier when rare.....

Only bisexual or heterosexual female and heterosexual male participants were retained, leaving 1453 women (mean age+ s.d. . 26.17+7.28 years) and 213 men (28.35+10.11). Sample sizes and ages within each treatment were rare clean-shaven (female N . 479, 26.30+7.19; male N . 70; 29.91+11.58); rare beards (female N . 502, 26.02+7.68; male N . 76; 28.49+9.07); the even treatment (female N . 472, 26.19+6.95; male N . 67; 26.55+9.43). Ethnicities were 70.47% European, 9.6% Asian, 6.12% Central/South American, 2.46% Oceania, 2.28% African/Middle Eastern, 1.86% Native North American and 7.2% chose not to answer.

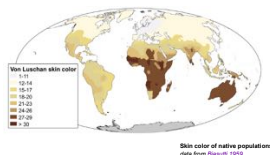
## Sexual dimorphism in pigmentation



skin reflectance test



protecting folate from UV while using UV for making vitamin D  
women are on average 2-3% lighter than men across populations

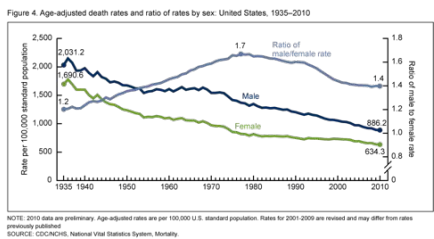


On average, females are slightly lighter than male across human populations. there is no strong evidence for sexual selection based on skin color.

Practice question: Levels of melanin, the dark pigment responsible for aviation in human skin pigmentation can be both, protective and disadvantageous for biological processes. Name two such processes

Production of Vitamin D requires sufficient UV absorption, at higher latitudes, darker skin can prevent sufficient vitamins D photosynthesis, lack of pigmentation is a strong risk factor for sunlight damage to the DNA of skin

Sexual Dimorphism in mortality



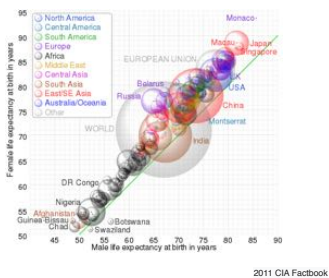
Males perish more at every age. This explains why there are so many more elder women alive in most populations.

One of the reasons includes the fact that males lack a second copy of their X chromosome, effectively being haploid (single copy) for hundreds of genes on this chromosome.

Practice question: Name one reason why males have higher mortality.

They only carry one copy of the X-chromosome, if one of the hundreds of genes on this chromosome is mutated, males have no back-up, but females do.

Sexual Dimorphism in Life Expectancy



In most population women live longer than males.

Botswana and Swaziland have higher male life expectancy, almost all other countries have higher female life expectancy.

Sexual Difference in Reproductive Variance

Table 1. Mean and variance in reproductive success (RS) of males and females in 18 populations*										
Country	Population or ethnic group	N	Mean <sub>m</sub>	Mean <sub>f</sub>	Var <sub>m</sub>	Var <sub>f</sub>	V <sub>m</sub> :V <sub>f</sub> ratio	Mating system <sup>b</sup>	Ref.	
Finland	1745-1900 genealogies	129	3.4	2.1	138	3.3	7.8	2.81	Monogamy	
Norway	1700-1900 genealogies	955	4.7	3.3	89	4.5	6.3	1.02	Monogamy	
Pitcairn Island	Genealogical records	145	4.6	23.6	127	4.7	23.2	1.04	Monogamy	
Zen	1825-1895 genealogies	1201	2.1	11.5	1059	2.4	5.7	1.18	Polygynandry	
Sweden	Local population	130	4.4	14.3	124	5	11.6	1.40	Monogamy	
Dominica	Yoruba-Torokoro	257	5.1	21.9	3.3	7.1	5.16	1.86	Monogamy	
Tanzania	Pitchame	138	6.0	9	154	6.1	7.3	1.24	Serial monogamy	
USA	General social survey	1099	2.0	2.3	134	2.0	1.8	1.22	Monogamy	
Central African Republic	Asia	29	6.3	6.6	34	6.2	3.2	1.63	Polygynandry	
Botswana	Dobe-Kung	35	5.1	8.8	62	4.7	4.9	1.77	Serial monogamy	
Tanzania	Hakia	64	4.3	6.8	44	3.4	5.1	1.83	Polygynandry	
Venezuela	Yanomamo	279	3.7	10.1	380	3.4	4.4	2.30	1.11	Polygynandry
Chad	Digahia	44	6.6	16.0	35	6.4	6.5	1.72	Polygynandry	
Kenya	Arabe	23	10.3	14.4	22	8.3	5.1	2.48	2.28	Polygynandry
Kenya	Kisumu	62	10.9	24.4	280	6.6	5.9	4.18	2.52	Polygynandry
Kenya	Maasai	40	6.4	16.1	79	7.6	3.6	4.29	3.16	Polygynandry
Kenya	Dogon	44	6.1	10.7	48	3.2	2.3	4.76	2.47	Polygynandry

\*Most studies report lifetime RS as the number of live births, or children born to a female, by age 45, of all daughters and sons and women. Where the mean RS for males is not reported, the value is estimated from the average RS of females. Where the variance is not reported, the value is estimated from the variance in average RS of males and females (the same pattern of results was found when this variance is used instead of V<sub>m</sub> in the analyses regarding mating system).

<sup>b</sup>Column headings abbreviate (1) 'L' for the opportunity for additional males and females, where + means RS is divided by the square of the mean RS (V<sub>m</sub>/V<sub>f</sub>), (2) 'P' for polygyny, (3) 'S' for serial monogamy, and (4) 'M' for monogamy. The values are rounded to the nearest integer.

<sup>c</sup>Column heading abbreviates (1) 'L' for the opportunity for additional males and females, where + means RS is divided by the square of the mean RS (V<sub>m</sub>/V<sub>f</sub>), (2) 'P' for polygyny, (3) 'S' for serial monogamy, and (4) 'M' for monogamy. The values are rounded to the nearest integer.

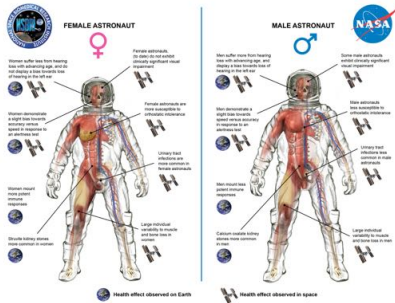
<sup>d</sup>Column heading abbreviates (1) 'L' for the opportunity for additional males and females, where + means RS is divided by the square of the mean RS (V<sub>m</sub>/V<sub>f</sub>), (2) 'P' for polygyny, (3) 'S' for serial monogamy, and (4) 'M' for monogamy. The values are rounded to the nearest integer.

Men can father many more babies than women can give birth to. Depending on the prevailing cultural norms, many populations have very similar variance in reproductive success (number of children) between males and females. certain cultural practices such a polygamy and many successive monogamous pairing can give rise to strong (4X) discrepancies between male and female variance in reproductive success.

Practice question: What does variance in reproductive success mean and why can male variance be so much larger than female variance?

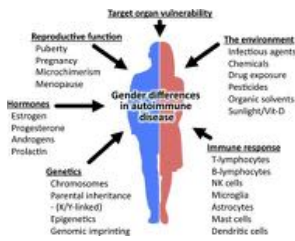
Both males and females can fail to produce a single offspring, but males can potentially have hundreds of offspring while most females face a limit of 20 or so maximum offspring.

## Sexual Dimorphism on earth and in space



Nowhere have female and male human bodies been more closely scrutinized than among our astronauts. Both on earth and in space, there are differences in physical issues, including vision, hearing loss, accuracy versus speed in alertness tests, types of kidney stones, urinary tract infections, and immune response.

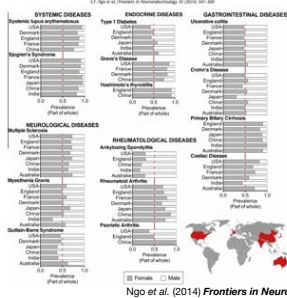
## Sexual Difference in the immune system



Ngo et al. (2014) *Frontiers in Neuroendocrinology*

Factors underlying sexual dimorphism in autoimmune disease. While the underlying basis for sexual dimorphism in autoimmune disease is yet to be determined, a number of factors may contribute to gender differences in autoimmune disease. Females show increased immune reactivity, differences in the number or responsiveness of cells that constitute the immune response, and differential resistance to target organ damage, and this may influence propensity to autoimmune disease. Hormonal changes during pubertal maturation, pregnancy, and menopause may alter susceptibility to autoimmunity, and it is generally accepted that pregnancy is associated with improved symptoms in autoimmune disease. The protective effects that are exerted by female (estrogen, progesterone, and prolactin) and male (androgens) hormones may also explain gender differences in specific autoimmune diseases. Differential exposure to environmental factors (including sunlight) can influence the prevalence and risk of developing an autoimmune disease or the severity of disease. Genetic factors that might influence the gender specific development of autoimmune disease may be related to susceptibility genes, chromosomal differences, or epigenetics. When genetic factors are combined with environmental factors, this can influence parental inheritance of autoimmune disease. Epigenetic changes that

## Sexual Difference in the immune system



Ngo et al. (2014) *Frontiers in Neuroendocrinology*

Most autoimmune diseases are more common in women than men in populations across the planet. The higher strength of female immunity over all appears to come at a cost.

Practice question: Name there different autoimmune disorders atet are more prevalent in women than men.

Multiple Sclerosis, Coeliac Disease, Lupus.

## Sexual dimorphism in mental health

Disorder	Women/Men Lifetime Incidence Ratio
PTSD	2.50*
Panic Disorder	1.98*
Generalized Anxiety	1.88*
Major Depressive Disorder	1.79*
OCD*	1.91*
Alzheimer's Disease	1.30*
Bipolar Disorder	~1.0*
Schizophrenia	0.71*
Parkinson's Disease	0.53*
Drug Use Disorder	0.51*
Alcohol Dependence	0.49*
ADHD	0.42*

Cover, K. et al. *Translat. Psych.* 2014

Sex differences in the lifetime incidence of psychiatric disorders vary from higher incidence in women, to no differences, to higher in men. Women/men lifetime incidence ratio was obtained directly from the publications referenced within the table or were calculated from the percentages of lifetime incidence published in the referenced studies.\*Of note, a sex bias for OCD is under debate and may depend on age; one study reports greater incidence among boys than girls. ADHD, attention deficit hyperactivity disorder; OCD, obsessive compulsive disorder; PTSD, posttraumatic stress disorder.

Obviously many of these disorders are subject to huge cultural generated impact on mental well-being: experienced threats such as those experience by many women exposed to male behavior can easily contribute to things like anxiety. Autism spectrum disorders are almost 3X more common in males and are very unlikely to be affected by culture given their origin in the womb.

Practice question: Name a category of mental disorder that is much more common in males than females.

## Mental health PTSD



Mendoza et al. *Molecular and Cellular Endocrinology* 2016

Gender differences in the development of PTSD. Evidence suggests that during PTSD development, an increased release of corticotrophin releasing factor (CRF) induces an abnormal activation of the HPA axis and release of cytokines. In turn, cytokines such as IL-6, IL-1 and TNF- $\alpha$  can regulate stress responses by modulating glucocorticoid receptor (GR) and adrenocorticotrophic hormone (ACTH) release. Evidence suggests that women have higher incidence of depression, migraine, insomnia and PTSD than men counterparts. This different susceptibility is attributed to hormonal and immune factors. Studies show that hormones such as estrogen, progesterone and dehydroepiandrosterone influence PTSD development by controlling the release of ACTH and activation of GR as well as the immune responses to psychological stress.

## Sexual Difference in iron deficiency Anemia

Table 4.4. Sex-related differences in iron deficiency anemia in adults

Researcher(s)	Year	Location	N	Sexual difference
Hallberg	1970	Sweden	1877	more in females
Jonsson et al.	1991	Iceland	4240	more in females
Kilpatrick	1970	England	7	more in females
Kilpatrick	1970	Wales	800	more in females
Kilpatrick	1970	Wales	800	more in females
MacPhail and Bothwell	1992	Africa		more in females
MacPhail and Bothwell	1992	North America		more in females
MacPhail and Bothwell	1992	Latin America		more in females
MacPhail and Bothwell	1992	East Asia		more in females
MacPhail and Bothwell	1992	South Asia		more in females
MacPhail and Bothwell	1992	Europe		more in females
MacPhail and Bothwell	1992	Oceania		more in females
Seibald	1970	Germany	1216	more in females
Sollan	1964	France	147	more in females
Vellar	1970	Norway	1439	more in females

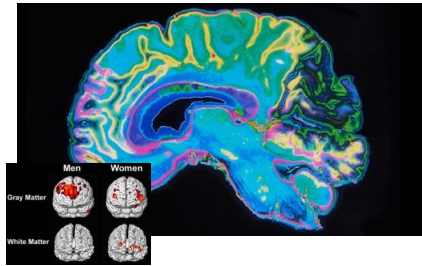
Stuart Macadam, P., 1998

Women around the world often suffer from iron deficiency anemia. This problem is compounded by large losses of blood during menstruation. Such anemia (lack of appropriate count of red blood cells) when chronic causes telltale skeletal signs (porosity behind the eye sockets in the skull). In ancient skeletons, such signs only appear once humans became farmers, starting around 10,000 years ago.

Practice question: Has iron deficiency anemia been part of ancient human evolution?

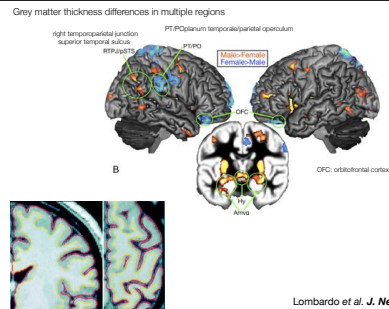
Unlikely, clear skeletal signs of iron deficit anemia are only seen from skeletons after the introduction of farming.

## Sexual Difference in the brain



Researchers have identified several structural differences between the brains of men and women, but it's impossible to tell the sex of an individual based solely on MRI images of the brain like the one above. Gray matter (neuronal cells bodies) and white matter (connections between cells) can differ between male and female brains.

## Sexual Difference in the brain



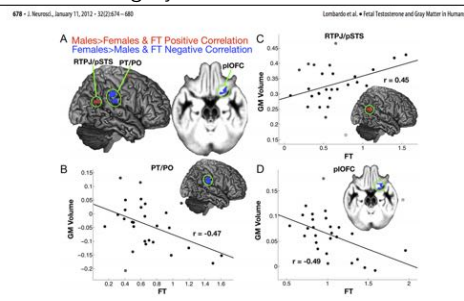
Lombardo et al. *J. Neuroscience* 2012

FT correlations with local GM volume. A, Areas where FT predicts local gray matter volume. Red/orange voxels denote positive correlations; blue voxels denote negative correlations. B, Areas of sexual dimorphism in local GM volume. Red/orange voxels denote a Male > Female pattern; blue voxels denote a Female > Male pattern. Voxels are the units of measurement in 3D brain imaging, each voxel corresponds to the 3-D pixel in the images.

Practice question: Are there anatomical differences between male and female human brains?

Yes, measurements using Magnetic Resonance Imaging (MRI) reveal differences in grey matter (cell body dense regions) thickness in several areas.

## Fetal Steroids and grey matter in the brain



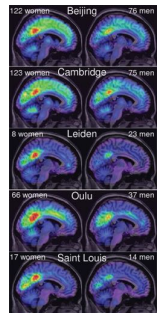
Lombardo et al. *J. Neuroscience* 2012

Fetal testosterone was measured in the amniotic fluid taken during pregnancy examination (amniocentesis) of each of the individuals whose brain was studied two decades later. Grey matter thickness in different areas correlated with Fetal testosterone, both positively and negatively depending on the region. Some areas overlap of FT-GM correlations and sexual dimorphism. A, Conjunction analysis overlap between sexual dimorphism and FT correlation in PT/PO, pOFC, and RTPJ/pSTS. Red voxels show overlap from the conjunction of FT positive correlation and Male > Female; blue voxels show overlap from the conjunction of FT negative correlation and Female > Male. B, Scatterplot showing the partial correlation between FT and GM volume within sexually dimorphic voxels in right PT/PO. Adjusted predictor and outcome values are plotted on the x and y axes. C, Scatterplot showing the partial correlation between FT and GM volume within sexually dimorphic voxels in RTPJ/pSTS. Adjusted predictor and outcome values are plotted on the x and y axes. D, Scatterplot showing the partial correlation between FT and GM volume within sexually dimorphic voxels in right pOFC.

Practice question: How was it possible for researchers to measure fetal hormones and then correlate these with brain anatomy?

By measuring hormone levels in amniotic fluid taken as part of prenatal checks (amniocentesis) and using MRI imaging of the

## Functional connectivity



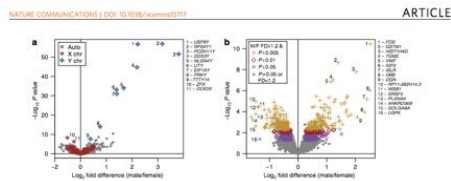
Tomasi & Volkov Gender Differences in Brain Functional Connectivity Density *Hum Brain Mapp.* 2012

Functional connectivity as measured by DTI (diffuser tension imaging) is higher in women than men.

This method measures the orientation of water molecules along the myelinated fibers in the brain.

Differences between male and female functional connectivity, but degrees vary with human populations!

## Sexual dimorphism in gene expression



16 k genes expressed in brain

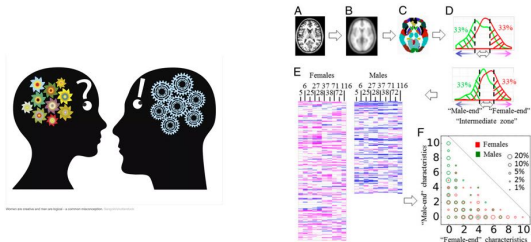
Gene expression in human brain implicates sexually dimorphic pathways in autism spectrum disorders. Werling, DM et al. *NATURE communications* 2016

The same genes that are expressed more in male brain cells (astrocytes that nurture neurons) are also connected to Autism spectrum disorder (ASD) when they carry mutations. ASD is three times more common in boys than girls. Microglia and astrocyte markers and genes upregulated in ASD brain tend toward higher expression in adult male brain. (a) Volcano plot for the differential expression results from all 16,392 transcripts expressed in the adult BrainSpan sample (n male 29 samples from 5 subjects, n female 29 samples from 5 subjects). (b) Subset of the volcano plot in a for all 15,724 autosomal transcripts.

Genes more expressed in male brains are also more involved in autism spectrum disorder!

## The danger of neurosexism

A study of 1400 brains (116 regions each) demonstrates that, although there are sex/gender differences in the brain, human brains do not belong to one of two distinct categories: male brain/female brain.

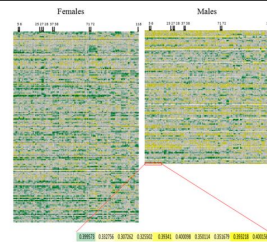


Joel et al. Sex beyond the genitalia: The human brain mosaic *PNAS* (2015)

## Measures of cellular architecture, connectivity and thickness of cortex

appear different between males and females in some areas but the majority of brain areas in a given brain form a composite of female or male patterns.

## The human brain mosaic

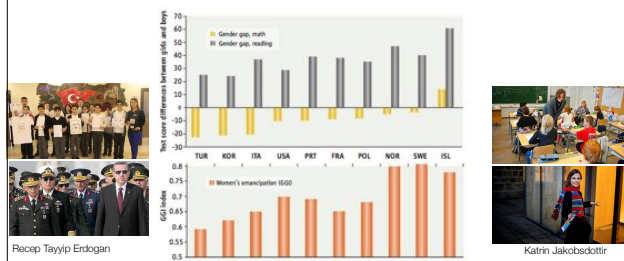


A study of 1400 brains (116 regions each) demonstrates that, although there are sex/gender differences in the brain, human brains do not belong to one of two distinct categories: male brain/female brain.

Joel et al. *Sex beyond the genitalia: The human brain mosaic* **PNAS** (2015)

The human brain mosaic. The gray matter volume of all 116 regions of gray matter in females (Left) and in males (Right) from the first sample is represented using a continuous high-low (green-white-yellow) scale. Each horizontal line represents the brain of a single subject and each column represents a single brain region. The continuous high-low scale represents the relative volume of a brain region in a given brain relative to the volume of this brain region in all other brains (i.e., within a column). The regions that showed the largest sex/gender differences and were included in the internal consistency analysis are marked with a black bar. The number above each bar corresponds to the region's number in the AAL (automatic anatomical labeling) atlas (Inset) Magnification of a small part of a horizontal line (i.e., a single brain). The number in each colored cell is the volume of this region for this brain.

## Sexual Dimorphism in school performance?



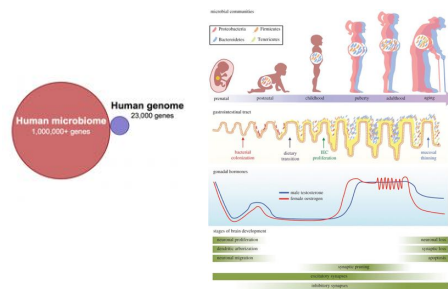
Guiso et al. *Science* 2008

Math and reading gender gaps. In more gender-equal cultures, the math gender gap disappears and the reading gender gap becomes larger. (Top) Gender gaps in mathematics (yellow) and reading (gray) are calculated as the difference between the average girls' score and the average boys' score. A subset of countries is shown here (see SOM for complete data set and calculations). In many countries, on average, girls perform more poorly than boys in mathematics. In all countries, girls perform better than boys in reading. The gender gap in mathematics and reading correlates with country measures of gender status within the culture, one of which measures is the GGI (bottom). Larger values of GGI point to a better average position of women in society. Besides USA, the countries are abbreviated as their first three letters, except for PRT, Portugal, and ISL, Iceland.

**Practice Question:** What is the relationship between gender equality and gender gap in mathematics and reading performances in schools across societies?

With more gender equality, the gender gap diminishes for math but remains large for reading.

## Sexual Difference in the microbiome



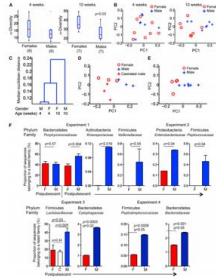
Jas'arevic' E, Morrison KE, Bale TL. 2016 Sex differences in the gut microbiome – brain axis across the lifespan. *Phil. Trans. R. Soc. B*

It is unclear how if and much the gut microbiome differs between males and female., Hormonal and immune system differences could likely contribute to differences in these complex communities.

## Sexual Difference in the microbiome



Markle et al. Sex Differences in the Gut Microbiome Drive Hormone-Dependent Regulation of Autoimmunity. *Science* 2013



In mice, there is strong evidence for an effect of sex on gut micro biome

Practice question: What effects could microbiome differences between women and men have ?

They could drive regulation of immunity.

## Sexual Difference in flatulence?

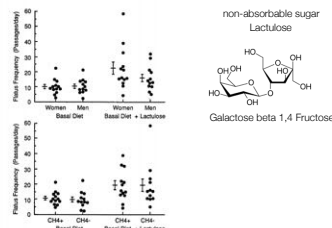


Fig 3. Flatulence frequency of men versus women (upper panel) and methane production versus methane degradation (lower panel) on the basal and lactulose supplemented diets.

Turn & Levitt. *Digestive Disease and Sciences* (1996)

No evidence for differences in farting frequency between males and females.

Males in our culture appear to take more pride/less shame in their product!!!

Practice question: Is there a difference in flatulence (farting frequency) between men and women?

NO, and both sexes can be caused to fart more when given flatulogenic diets....

## Boy raised as a girl



John Money  
psychologist/sexologist



Milton Diamond  
biologist/sexologist



David Reimer  
August 22, 1965 – May 4, 2004  
22 months (Brenda), 14, 20 (David), 25, 39



Book by John Colapinto

The tragic consequences of being assigned another sex than one feels one is!

Milton Diamond was driven to expose Money's fake claims in an attempt to protect many additional children from going through what David went through.

Sex Reassignment at Birth: A Long Term Review and Clinical Implications Author(s): Milton Diamond, Ph.D. and H. Keith Sigmundson, M.D. Published: Archives of Pediatrics and Adolescent Medicine, No. 151 (March 1997)

<http://www.hawaii.edu/PCSS/biblio/articles/1961to1999/1997-sex-reassignment.html>

Practice question: What tragic lesson could be learnt from the story of David Reimer, a boy raised as girl due to a botched circumcision?

Gender identity can have deep biological roots that can't be easily shaped by

## Origins sexual Dimorphism



Male-male competition: Nuba wrestler, Sudan, Schwingen (wrestling), Switzerland



female choice: Wodaabe, Niger Maasai dancers, Kenya, Tanzania



Larger male size could be due to male-male competition, female choice for larger body size and all kinds of male attributes, sexual division of labor or any combination thereof

Practice question: What could be the evolutionary origins of sexual dimorphism?

Need for larger bodies and more aggression in males due to importance of male-male competition, Sexually selected traits, selected by one sex in the other can produce surprising traits, biological requirements such as lactation affect shape only one sex (female milk production in mammals), differences in social cognition could be shaped by the nature of social system (female bonded, pair bonded, male bonded).....

## Sexual division of labor, sex-specific ecology

Gatherer-Hunters



Sexual division of labor in the Hadza of Tanzania. Most documented hunter gatherers have males who do most of the hunting, even though female bring in more calories through gathering. Such division of labor/differential exploration of natural resources could also select for differences in size and muscularity.

When women hunt, they usually go after less risky but more predictable prey (Martu in Australia where women hunt many lizards, and men go after kangaroos)

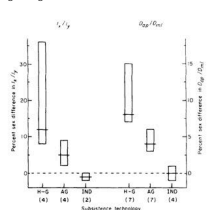
Practice question: What does the existence of sexual division of labor in many hunter gatherer societies mean for the age of such division?

That such division of labor predates agriculture that only began in the last ten thousand years.

## Subsistence strategy and skeletal dimorphism

femoral midshaft bending strength

external diameter



H-G: Foragers AG: Farmers IND: Industrial

Ruff, C. J. *Human Evo.* 1987

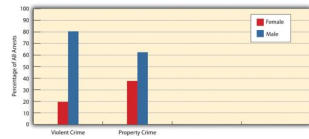
Sexual dimorphism in two measures of relative bending strength of the femoral midshaft in three broad subsistence categories.

Mode of substance can rapidly change sexual dimorphism as shown for North American Inuits, farmers and city dwellers!

Practice question: What is the difference in sexual skeletal dimorphism (bone bending strength) between hunter gatherers and industrial societies?

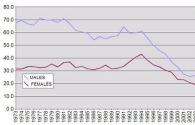
Sexual dimorphism is much diminished in industrial societies.

## Sexual differences in aggression



Data from Federal Bureau of Investigation, (2011). Crime in the United States, 2010. Washington

Violent crime rates by gender 1973-2003, per 1,000 people. (data: Bureau of Justice Statistics).



Being male, i.e. possessing a Y-chromosome makes human much more likely to be violent.

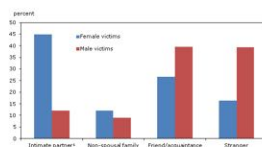
## Violence against women

Prevalence of intimate partner violence by region



Females non the other hand are m much more likely to experience violence. This risk exists already early in life.

## Sexual differences in victims of violence



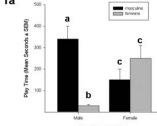

Canada 2011  
Canadian Centre for Justice Statistics, Incident-based Uniform Crime Reporting Survey.

This statistic from Canada shows that females are most often the target of intimate partner violence while males experience violence from strangers more often.

Most of this violence is perpetrated by males.

# Toy preference in captive rhesus monkeys

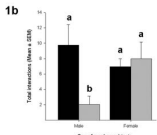

**1a**



Sex of human subjects	Male (Black)	Female (Grey)
Mike	~350	~20
Farrah	~150	~250

Berenbaum SA, Hines M. Early androgens are related to childhood sex-typed toy preferences. *Psychological Science*. 1992;

**1b**



Sex of interacting subjects	Male (Black)	Female (Grey)
Mike	~10	~2
Farrah	~8	~10

J.M. Hassett, E.R. Siebert, K. Wallen  
Sex differences in rhesus monkey toy preferences parallel those of children  
*Horm Behav* (2008)

Figure 1a: Human Sex difference in play with stereotypical masculine and feminine toys in a choice paradigm. Different superscripts within category or within sex indicate significant differences. (Adapted from Berenbaum and Hines, 1992).

Practice question: What could be the reason why male young rhesus monkeys prefer toy cars and females prefer plush toy animals?

# Sex, gender, gender identity

Biology and Culture giving rise to multi-dimensional rainbows!

### SEXUAL ORIENTATION

### GENDER IDENTITY

*David Weinbaum*

Three times more males than females undergo sex change. (does this reflect larger variance for many traits in males?)

With many more men self-reporting to be exclusively homosexual and three times more men transitioning to female, there seems to be an a symmetry.

Why this should be is a very interesting question.

# Summary

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Sexual Dimorphism refers to differences between biological characteristics between the sexes (anatomy, gene expression, physiology, and behavior).

Reconstruction of ancient sexual dimorphism is very difficult, but skeletal and dental remains allow some inferences.

The major drivers of sexual dimorphism are genes (on sex chromosomes and others) and hormones. Humans are sexually dimorphic in many ways and to varying degrees.

Dimorphism ranges from almost perfectly bimodal to gradual, depending on the trait measured.

Most sexually dimorphic traits overlap, males often have a higher variance

Sexual dimorphism extends to development, immunity, life expectancy and behavior.

Neuronal sexual dimorphism is very complicated, but genetic sex and hormones strongly affect brain development.

Neuronal sexual dimorphism is very complicated, but genetic sex and hormones strongly affect brain development.



