

5. Sexual Dimorphism



ANBI 116 Evolution of Sex
Pascal Gagneux

January 18, 2022

Current sexual Dimorphism in primates

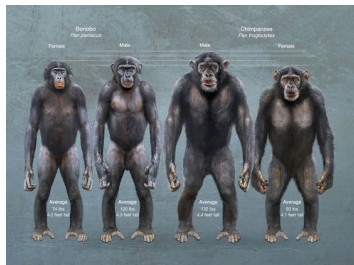


Four different primate species with striking sexual dimorphism: Asia: Proboscis monkeys, orangutans, Africa: mandrills, and Gorillas

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 our closest living relatives



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

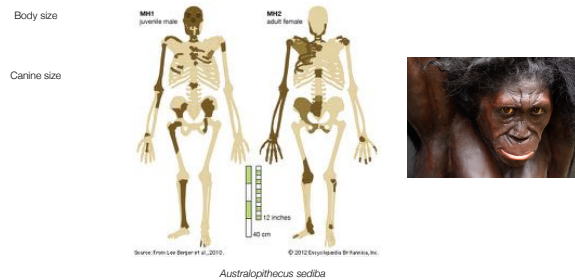


There is a lot of interest in reconstructing the appearance of extinct hominids (individuals of species belonging to any of the species that were ancestors to humans or closely related to those ancestors). Without large numbers of almost complete skeletons, this is very difficult to do. Neanderthals, 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?

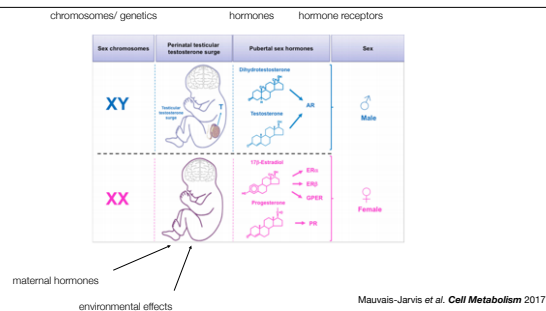
We could consider males and females from a strongly sexually dimorphic species as two different species.

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



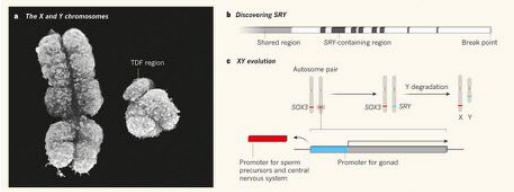
Sex differences in physiology begin during development from the combination of genetic and hormonal events and they continue after puberty. They result from the combination of the cell-autonomous effect of sex chromosomes, the organizational action (masculinization) of the testicular testosterone surge 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?

Lipids.

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. 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. 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?

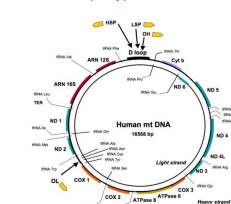
Yes, the X chromosome.

The human Y-chromosome, mostly **one haplotype**



just small caps of the Y chromosome, the pseudoautosomal regions (PAR), recombine with homologous regions on the X!

Human **mitochondrial DNA** is also **one haplotype**:



The Y-chromosome: largest haplotype in the genome

Practice question: How many genes are there on the human X-chromosome and how many on the Y?

Over 1000 and under 100.

Sex Chromosomes: discovered by Nettie Stevens



Nettie Maria Stevens

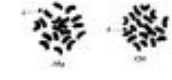
She was a trained expert in the modern sense—in the sense in which biology has ceased to be a playground for the amateur and a plaything for the mystic. Her single-mindedness and devotion, combined with keen powers of observation; her thoughtfulness and patience, united to a well-balanced judgement, accounts, in part, for her remarkable accomplishment.

T. H. Morgan



Plate IV from Stevens (1905) showing hand-drawn micrographs from *Tenebrio molitor* (Meal worm beetle) samples

STEVENS.



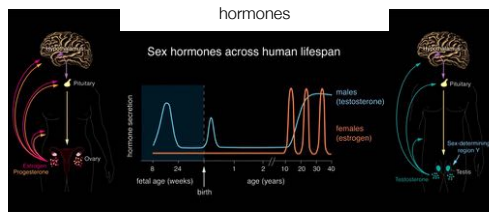
19 large chromosomes + 1 small chromosome in male

20 large chromosomes in female

20 large chromosomes or 19 large and one small chromosome.

Thomas Hunt Morgan wrote her obituary in 1912 but did **not** credit her for her discovery.

Origin of sex differences



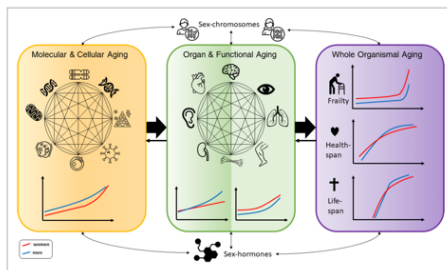
Three distinct spikes testosterone in males, 2 in early life: early gestation and one after birth and one during and after puberty

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.

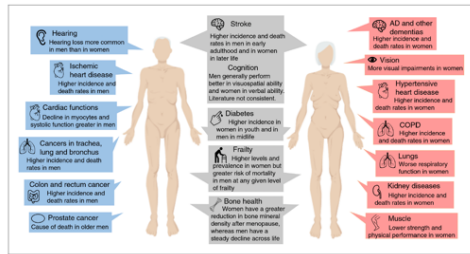
Sex differences in aging



Li et al., eLife 2021

Conceptual framework of the complex interactions between molecular, cellular, functional, organ, and whole body aging processes across the life course in men and women, with influences from chromosomes and hormones on the sex differences.

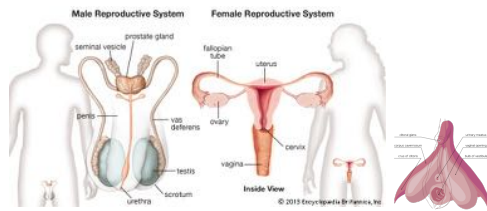
Sex differences in aging



Li et al., eLife 2021

Overview of the most significant sex differences in age-related diseases, functioning and frailty. Abbreviations: AD, Alzheimer's disease; COPD, chronic obstructive pulmonary disease.

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.....

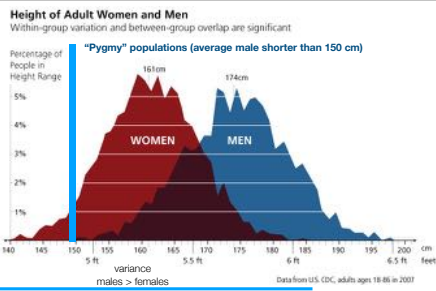
If anything, male organs are female turned inside out....

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.

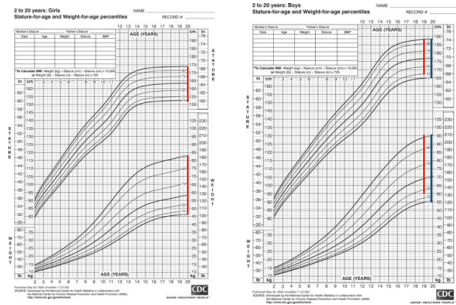
Sexual Dimorphism in body size, height



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!!!!

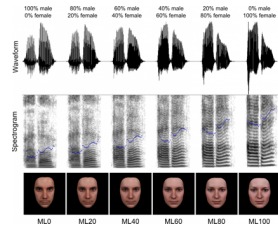
Sexual Dimorphism growth pattern



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



Skuk, Y. G., & Schweinberger, S. R. (2014). Influences of fundamental frequency, formant frequencies, aperiodicity 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 cords and develop their adams apple.

This “apple” is technically a laryngeal protuberance formed by thyroid cartilage which helps protect the walls and the frontal part of the larynx, including the vocal cords (which are located directly behind it).

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...)

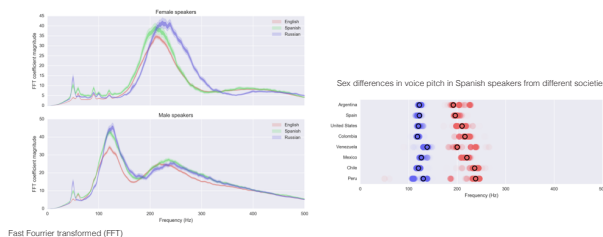
Practice question: What is one of the most sexually dimorphic aspects of human language?

Voice pitch.

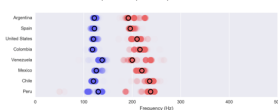
also:

Earlier acquisition by females.

Sexual Dimorphism language and voice

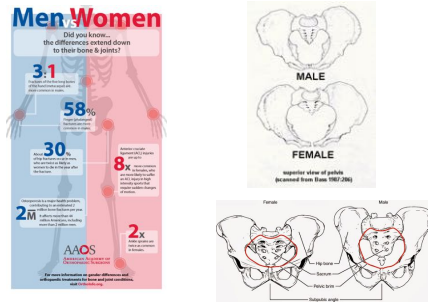


Sex differences in voice pitch in Spanish speakers from different societies



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...)

Sexual Dimorphism in bone and joints

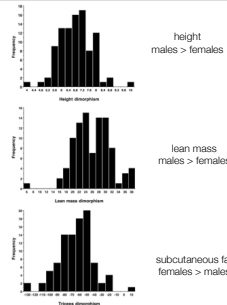


Sexual dimorphism in humans also exists in the skeleton and the joints. The pelvis and the Skull are often used by forensic scientists to identify the sex of human remains. the skull is more robust in males and the pelvis wider in females

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, 411–419.

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.

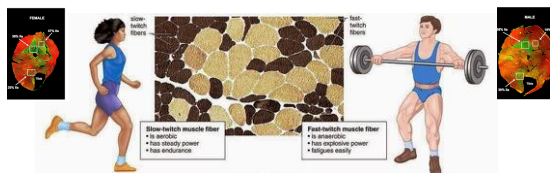
Subcutaneous fat.

Sexual Dimorphism in muscle fibers

muscle fiber type distribution



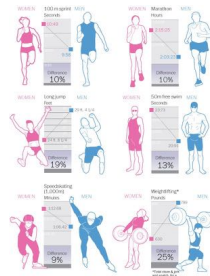
> 3000 genes are differentially expressed in male and female skeletal muscle



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

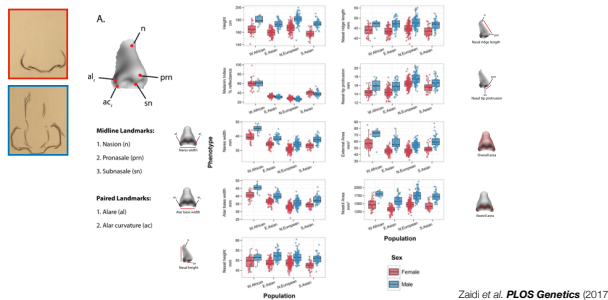


Estimates of athletic performance gaps, gaps have remained very stable since 1983

Athletes competing in top level competitions such as the olympics, exemplify the extremes of capacity in both sexes.

training and biological constitution contribute to their performances. The gaps between females and males have remained remarkably steady since 1983.

Sexual Difference in Nose size & Shape



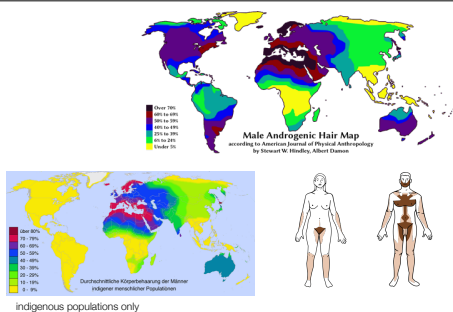
Zaidi et al. PLOS Genetics (2017)

A recent study by Mark Shriver at Penn State and colleagues measured hundreds of noses around the world. For most measurements, males had larger values than females, making the nose one of the really sexually dimorphic organs. The first two plots on the upper left show the variability and sex differences in height and in melanin index. % reflectance represent how much light from the measuring device bounces back off the skin.

Practice question: Apart from genitals, which external feature of the body differs the most between women and men?

The nose.

Sexual Dimorphism Hair



Facial and body hair are among the most varying features in our species and are also strongly sexually dimorphic.

Androgen hormones (testosterone and derivatives) can promote the growth of varying amounts of facial hair and body hair in males and females.

Androgen also promote hair loss from the head of males.

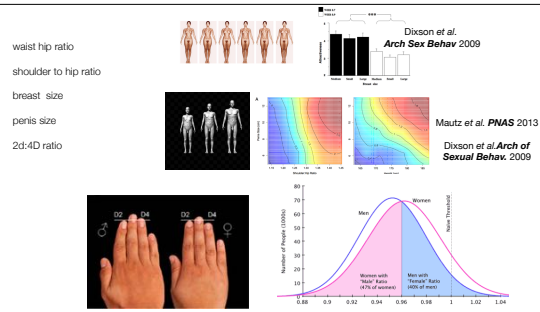
Practice question: Which East Asian population has the hairiest persons?

The Ainu of Japan.

Practice question: Does the degree of male hairiness in regions of the world say something about hairiness of female from the same populations?

Yes, females in populations with more hairy males tend to have slightly more pronounced body hair.

Sexual Dimorphism Body Shape and attractiveness



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.

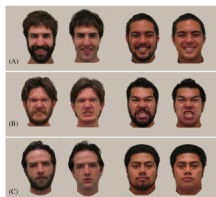
Shoulder to hip ratio and height.

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

Waist hip ratio and breast size

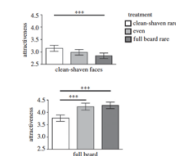
Sexual Dimorphism in Facial Hair

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



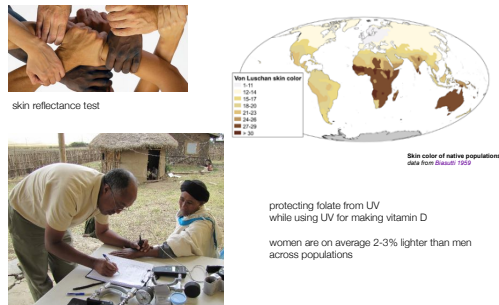
Janif ZJ, Brooks RC, Dixon BJ. 2014 Negative frequency-dependent preferences and variation in male facial hair. *Biol. Lett.*

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.

Practice question: What factors might underlie preference for beards in humans?
Frequency (more attractive when rare) and perceived age and status.

Sexual dimorphism in pigmentation



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

Country	Population or ethnic group	N ^b	Mean _{males}	Var _{males}	Mean _{females}	Var _{females}	N ^c	Mating system ^d	Ref.	
Finland	1745-1800 generations	126	3.4	6	138	35	676	0.81 Monogamy	[861]	
Norway	1700-1800 generations	955	4.7	6.5	381	4.5	381	0.81 Monogamy	[862]	
Pitcairn Island	Genealogical records	145	24.6	23.6	12.7	4.7	2332	1.04 Monogamy	[360]	
Yemen	1925-1988 generations	267	5.1	6.1	1.8	0.6	1168	0.69 Polygyny/monogamy	[863]	
Sweden	1925-1988 generations	1201	2.1	1.15	1050	2.4	5.71	1.83 Monogamy	[864]	
Denmark	Local population	120	4.4	14.3	5.4	11.8	120	1.04 Monogamy	[865]	
Tanzania	Tschima	128	6.0	9	154	6.1	7.3	124	1.27 Serial monogamy	[866]
USA	General social survey	1069	2.0	23	1344	2.0	1.8	127	1.05 Monogamy	[867]
Central African Republic	Aka	29	6.3	8.6	3.4	6.2	8.2	1.62 Polygyny/monogamy	[868]	
Botswana	Dike Kung	35	8.1	8.6	6.2	4.7	173	1.61 Serial monogamy	[361]	
Tanzania	Sac	33	6.3	9.8	4.6	3.6	1.61	1.61 Polygyny/monogamy	[869]	
Venezuela	Yanomamo	279	3.7	10.1	380	3.4	44	2.36 2.1 Polygyny/monogamy	[890]	
Chad	Derga	33	6.5	8.0	3.3	6.4	2.08	2.08 Polygyny/monogamy	[891]	
Chad	Derga	29	10.3	14.4	26.2	6.8	2.82	2.28 Polygyny/monogamy	[900]	
Kenya	Kisumu	62	3.6	12.1	4.6	3.9	5.16	3.12 Polygyny/serial monogamy	[901]	
Brazil	Kapixá	42	10.9	24.4	20.0	6.6	4.18	4.82 Polygyny/serial monogamy	[91]	
Peru	Aché	48	6.4	15.1	2.9	2.6	5.36	4.22 5.16 Serial monogamy	[256]	
Malawi	Digwa	41	15.7	18	3.2	2.2	1.68	1.68 Polygyny/monogamy	[257]	

^a Most studies report *female* RE as the number of the sons, or children living to 50% of the age, for *male* RE as the number of sons and women. The mean REs for males and females are not equal, the ratio of male RE to female RE is 1.68. The ratio of male RE to female RE is 1.68. The ratio of male RE to female RE is 1.68. The ratio of male RE to female RE is 1.68.

^b The number of individuals in the sample. The number of individuals in the sample is 126 for Finland, 955 for Norway, 145 for Pitcairn Island, 267 for Yemen, 1201 for Sweden, 120 for Denmark, 128 for Tanzania, 1069 for USA, 29 for Central African Republic, 35 for Botswana, 33 for Tanzania, 279 for Venezuela, 33 for Chad, 29 for Chad, 62 for Kenya, 42 for Brazil, 48 for Peru, 41 for Malawi.

^c The number of matings per individual. The number of matings per individual is 0.81 for Finland, 0.81 for Norway, 1.04 for Pitcairn Island, 0.69 for Yemen, 1.83 for Sweden, 1.04 for Denmark, 1.27 for Tanzania, 1.05 for USA, 1.62 for Central African Republic, 1.61 for Botswana, 1.61 for Tanzania, 2.36 for Venezuela, 2.08 for Chad, 2.28 for Chad, 3.12 for Kenya, 4.82 for Brazil, 4.22 for Peru, 1.68 for Malawi.

^d The mating system. The mating system is Monogamy for Finland, Norway, Pitcairn Island, Sweden, Denmark, USA, Central African Republic, Botswana, Tanzania, Venezuela, Chad, Kenya, Brazil, Peru, Malawi. The mating system is Polygyny/monogamy for Yemen, Tanzania, Chad, Kenya, Brazil, Peru, Malawi. The mating system is Polygyny/serial monogamy for Kenya, Brazil, Peru, Malawi.

^e The ratio of male RE to female RE. The ratio of male RE to female RE is 1.68 for Finland, 0.81 for Norway, 1.04 for Pitcairn Island, 0.69 for Yemen, 1.83 for Sweden, 1.04 for Denmark, 1.27 for Tanzania, 1.05 for USA, 1.62 for Central African Republic, 1.61 for Botswana, 1.61 for Tanzania, 2.36 for Venezuela, 2.08 for Chad, 2.28 for Chad, 3.12 for Kenya, 4.82 for Brazil, 4.22 for Peru, 1.68 for Malawi.

^f The ratio of male RE to female RE. The ratio of male RE to female RE is 1.68 for Finland, 0.81 for Norway, 1.04 for Pitcairn Island, 0.69 for Yemen, 1.83 for Sweden, 1.04 for Denmark, 1.27 for Tanzania, 1.05 for USA, 1.62 for Central African Republic, 1.61 for Botswana, 1.61 for Tanzania, 2.36 for Venezuela, 2.08 for Chad, 2.28 for Chad, 3.12 for Kenya, 4.82 for Brazil, 4.22 for Peru, 1.68 for Malawi.

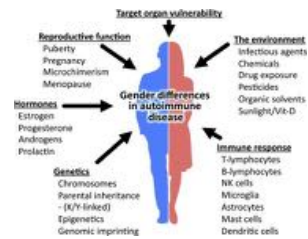
Practice question: What does variance in reproductive success mean and why can male variance be so much larger than female variance?

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.

[illegible]

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.

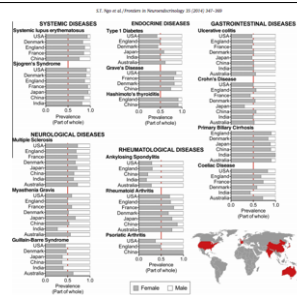
Sex Difference in the immune system



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 arise in autoimmune disease can be related to the sex of the parent, or can result from external factors. Genetic imprinting, and in particular, miRNA imprinting, could also contribute to the sexual dimorphism seen in autoimmune disease.

Sexual Difference in the immune system



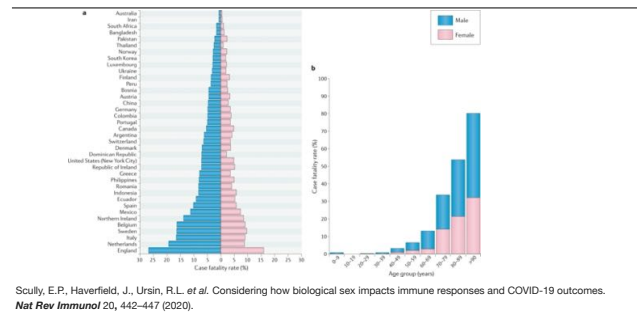
Ngo et al. (2014) *Frontiers in Neuroendocrinology*

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.

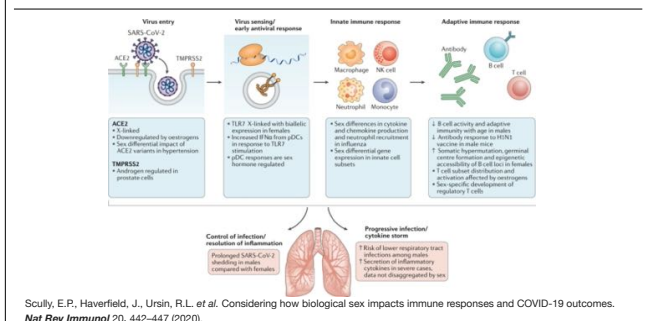
Multiple Sclerosis, Coeliac Disease, Lupus.

Sex Difference in Covid 19 mortality (38 countries)



a | COVID-19 case fatality rates (CFRs) for males and females across 38 countries or regions reporting sex-disaggregated data on COVID-19 cases and deaths. CFR was calculated as the total number of deaths divided by the total number of cases for each sex multiplied by 100. The male CFR is higher than the female CFR in 37 of the 38 regions, with an average male CFR 1.7 times greater than the average female CFR ($P < 0.0001$, Wilcoxon signed rank test). b | Average COVID-19 CFRs for males and females stratified by age. The data represent 12 countries currently reporting sex- and age-disaggregated data on COVID-19 cases and deaths (Australia, Columbia, Denmark, Italy, Mexico, Norway, Pakistan, Philippines, Portugal, Spain, Switzerland and England). The COVID-19 CFR increases for both sexes with advancing age, but males have a significantly higher CFR than females at all ages from 30 years ($P < 0.05$, Wilcoxon signed rank test). The data were obtained from Global Health 50/50 and official government websites of each respective country on 7 May and 8 May 2020. For more information on the data source for a specific country, please contact the corresponding author.

Sex Difference in Covid 19 mortality (38 countries)



Possible factors affecting differential disease outcomes in males and females after infection with Sars-Cov 2 virus.

Sexual dimorphism in mental health

Disorder	Women/Men Lifetime Incidence Ratio
PTSD	2.08*
Panic Disorder	1.98*
Generalized Anxiety	1.88*
Major Depressive Disorder	1.75*
OCD*	1.9*
Alzheimer's Disease	1.30*
Epilepsy Disorder	~1.0*
Schizophrenia	0.71*
Parkinson's Disease	0.63*
Drug Use Disorder	0.61*
Alcohol Dependence	0.40*
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 two categories each of mental disorder that is much more common in males than females and vice versa.

Schizophrenia and Autism Spectrum Disorder more common in males, PTSD and Major Depressive Disorder more common in 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- α 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
Jönsson 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	1800	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
Schödl	1970	Germany	1216	more in females
Sultan	1964	France	147	more in females
Vollrath	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.

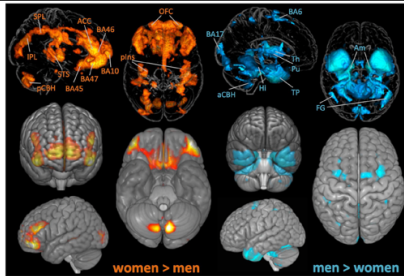
Such anemia (lack of appropriate count of red blood cells) when chronic causes telltale skeletal signs (porosity behind the eye sockets in the skull).

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.

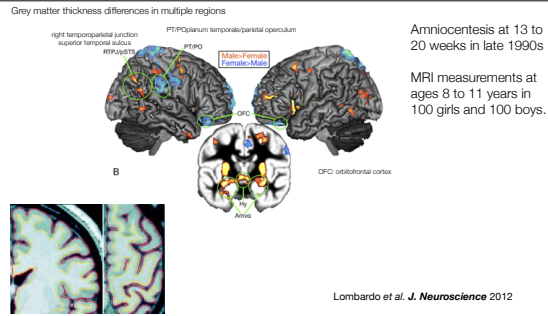
Sexual Difference (grey matter volume) in the brain



Lotze, M., Domin, M., Gerlach, F.H. et al. Novel findings from 2,838 Adult Brains on Sex Differences in Gray Matter Brain Volume. *Sci Rep* 9, 1671 (2019).

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. Significant sex differences for the combined cohort ($n = 2,838$). Glass brain projections with labels (top) and MNI-standard brain projections (bottom). Orange clusters display regions with larger gray matter volume in women (women > men): pCBH = posterior cerebellar hemisphere; IPL = inferior parietal lobe; SPL = superior parietal lobe; STS = superior temporal sulcus; ACC = anterior cingulate cortex; BA = Brodmann areas 45, 46, 47, 10; OFC = orbitofrontal cortex; plns = posterior insula. Blue clusters display regions with significantly larger gray matter volume in men (men > women): BA = Brodmann areas 6, 17; aCBH = anterior cerebellar hemisphere, Hi = hippocampus, Th = thalamus, Pu = putamen, TP = temporal pole, FG = fusiform gyrus, Am = amygdala). All findings are significant at $p \leq 0.05$, FWE corrected for multiple comparisons.

Sexual Difference in the brain

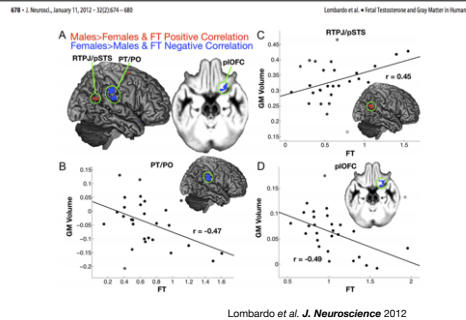


Fetal Testosterone correlations with local Grey Matter volume. A, Areas where FT predicts local gray matter volume. Red/orange voxels denote positive correlations; blue voxels denote negative correlations. B, Areas of sexual dimorphism in local GM volume. Red/orange voxels denote a Male > Female pattern; 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

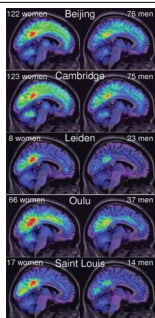


Fetal testosterone was measured in the amniotic fluid taken during pregnancy examination (amniocentesis) of each of the individuals whose brain was studied two decades later. Grey matter thickness different areas correlated with Fetal testosterone, both positively and negatively depending on the region.

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 brains decades later.

Functional connectivity

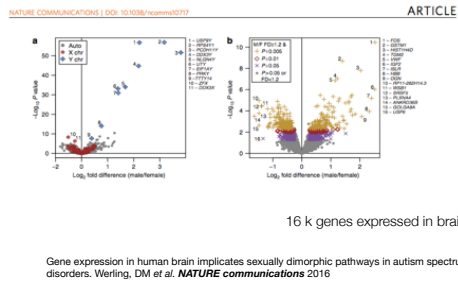


Functional connectivity as measured by DTI (diffusion tensor imaging) is higher in women than men.

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!

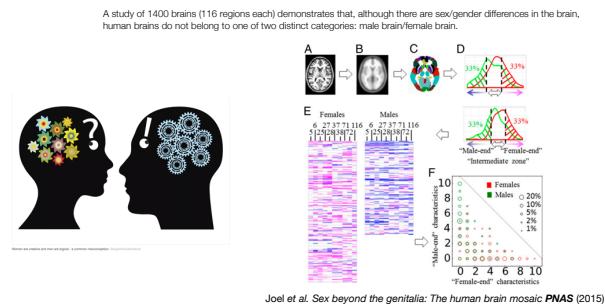
Sexual dimorphism in gene expression



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.

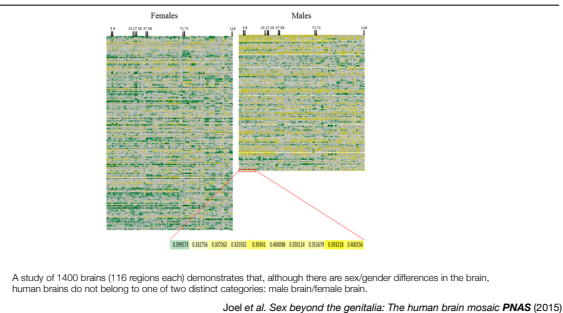
Genes more expressed in male brains are also more involved in autism spectrum disorder!

The danger of neurosexism



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



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?

Test score differences between girls and boys

Country	Gender gap, math	Gender gap, reading
TUR	-15	28
KOR	-10	30
ITA	-15	28
USA	-10	30
FIN	-10	38
FRA	-10	38
NOR	-10	35
POL	-10	42
SWI	-10	45
ISL	15	55

Women's emancipation 1990

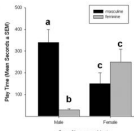

Country	Women's emancipation 1990 (GGI index)
TUR	0.58
KOR	0.62
ITA	0.65
USA	0.70
FIN	0.68
FRA	0.62
NOR	0.68
POL	0.82
SWI	0.85
ISL	0.82

Guiso et al. *Science* 2008

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

Toy preference in captive rhesus monkeys

1a



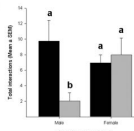

Sex	Toys (Mean Minutes)	Food (Mean Minutes)
Male	~350 (a)	~50 (b)
Female	~250 (c)	~300 (c)

Play Time (Mean Minutes (SD))

Sex of human subjects

Male Female

1b



Sex	Toys (Mean Minutes)	Food (Mean Minutes)
Male	~10 (a)	~2 (b)
Female	~7 (a)	~8 (a)

Total Play Time (Mean Minutes (SD))

Sex of monkey subjects

Male Female

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

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

Female primates might relate to toys with faces more, due to more empathy and/or sociality.

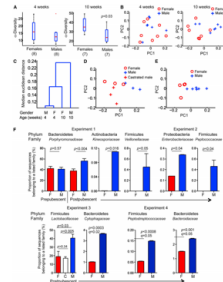
Sexual Difference in the microbiome

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?

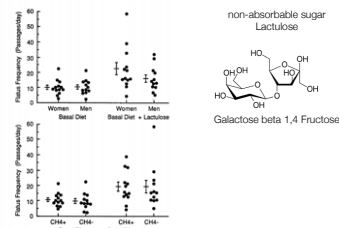


Fig 1. Flatulence frequency of men versus women (upper panel) and relative production versus relative consumption (lower panel) on the basal and lactulose supplemented diet.

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 the

environment.

Origins sexual Dimorphism



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



female choice: Wodaabe, Niger



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. Also, reduced size in females might be linked to higher Estrogen levels and the influence of this hormone on duration of growth.

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



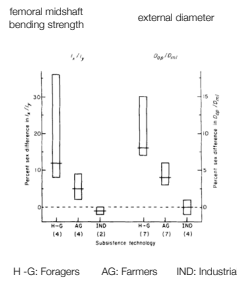
Sexual division of labor in the Hadza of Tanzania. Most documented hunter gatherers have males who do most of the hunting, even though female bring in more calories through gathering. Such division of labor/differential exploration of natural resources could also select for differences in size and muscularity.

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



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

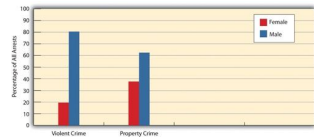
Sexual dimorphism in two measures of relative bending strength of the femoral midshaft in three broad subsistence categories.

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

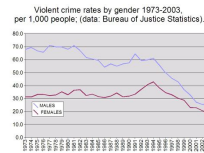
Practice question: What is the difference in sexual skeletal dimorphism (bone bending strength) between hunter gatherers and industrial societies?

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



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

Violence against women

Prevalence of intimate partner violence by region

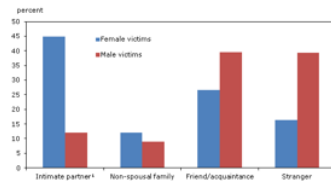


Violence starts early in the lives of women
Lifetime prevalence of intimate partner violence among ever-partnered women (WHO, 2010)

AGE GROUP (YEARS)	PREVALENCE (%)
15-19	29.4
20-24	31.6
25-29	32.3
30-34	31.1
35-39	36.6
40-44	37.8
45-49	29.2
50-54	25.5
55-59	15.1
60-64	19.5
65-69	22.2

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



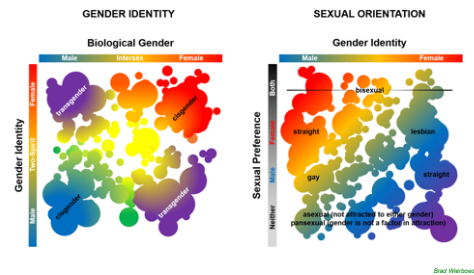
Canada 2011
Canadian Centre for Justice Statistics, Incident-based Uniform Crime Reporting Survey

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.

Sex, gender, gender identity

Biology and Culture giving rise to multi-dimensional rainbows!



An attempt to graphically depict the complicated landscapes of gender and sexual orientation in humans.

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

Interestingly, these plots are represented as symmetrical.

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

Why this should be is a very interesting question.

Summary



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.

