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A categorical gender assignment does not do justice to the variability of individuals

Female – male – diverse: Is it that simple?

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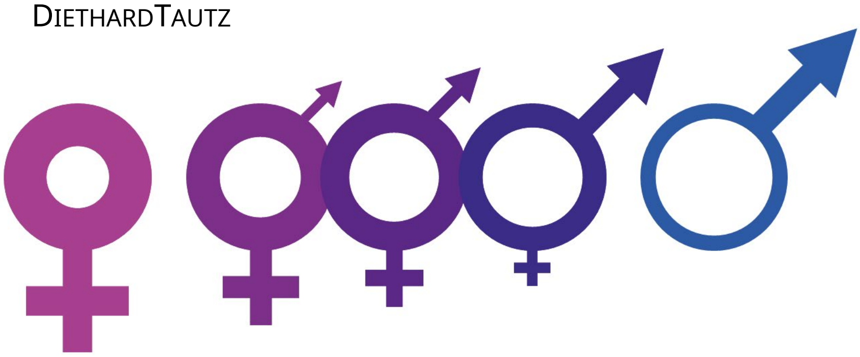

Image: P. Eitner.

The evolutionary biological function of sexual reproduction is to produce genetically different individuals. This creates a spectrum of phenotypes and behaviors between the sexes that should not be categorized.
The discussion about gender identities should focus on variability, not categories. This would allow to reconcile biological and sociological viewpoints.

Sexual reproduction is widespread in the animal and plant kingdoms. In 1949, Max Delbrück elevated this observation from a physicist's perspective to one of the foundations of biology: "*In the history of biology, discoveries of great generality can be found, such as the occurrence of sexual reproduction in all living forms and the cellular structure of organisms*" [1]. He was undoubtedly thinking of a binary sexuality with male and female individuals. In a biological definition, these two sexes can be determined by their binary gamete status (see also the article "Sex and *Gender*: A biological perspective" in this issue of BiuZ). However, the expression of gender can be very variable, so that it cannot be described with simple binary categories.

This insight has been slow to gain acceptance, but now the legislature is also taking it into account.

On November 1 of this year (2024), the Self-Determination Act [2] came into force. It allows anyone to change their gender entry and first name in the civil status register without having to go through a complicated procedure. For several years now, the civil status register has not only allowed the categories "female" and "male" to be entered, but also "diverse" as a third option. In 2017, the Federal Constitutional Court ruled that the general right to personality also protects the gender identity of those who cannot be assigned to either the male or female gender [3].

On the one hand, this sounds like a progressive development – especially compared to previous laws that dealt with gender identities. On the other hand, however, the legislator is once again emphasizing that there is a fundamental classifiability of genders – but now with the admission that not all people can be classified as female or male.

But does this really do justice to the phenotypic spectrum of individuals? And what is the aim of this classification? What does it mean to be male or female or diverse and why can you simply change it? In the charged discussion about the categories and fluidity of gender, one should not simply retreat to biological definitions of a fundamental two-gender system and declare *Gender* - diversity as anthropocentric [4]. If one looks at the question from an evolutionary and genetic perspective, one will find that a starting point that focuses on the variability of individuals provides a much better approach to understanding the sexes.

The Mystery of Sexual Reproduction

Evolutionary biology has been puzzling over which population genetic mechanisms are necessary to distinguish sexual reproduction from asexual reproduction for decades.

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THEORY TO SOLVING THE"*TWO - FOLD COST OF SEX*"-PROBLEM

1. Fisher-Muller hypothesis
The hypothesis is that sexual reproduction allows for faster evolution by bringing together beneficial mutations from different individuals. In asexual populations, beneficial mutations must occur one after another in the same lineage, which takes much longer. In sexual reproduction, several beneficial mutations can be combined in the offspring through recombination, increasing the overall adaptability of the population. However, this is only a long-term advantage and cannot adequately explain short-term evolution.

2. "Muller's ratchet"*hypothesis*
The hypothesis focuses on the fact that sexual reproduction can prevent the accumulation of harmful mutations. In asexual populations, mutations that reduce fitness can accumulate over generations without there being any way to eliminate them. This is what the term" ratchet"*(Each individual mutation is seen as a click in a ratchet that can no longer be reset. However, the recombination of chromosomes that accompanies sexual reproduction can cause such a "reset". This hypothesis also only explains the long-term consequences.*

*3.*Red Queen*hypothesis*
The hypothesis states that sexual reproduction is advantageous because it increases the possibility of rapid adaptation in the evolutionary conflict between parasites and hosts. Since parasites and pathogens can evolve quickly due to short generation times, sexual reproduction ensures The hosts need genetic diversity to quickly develop the necessary resistance. The conflict ultimately never ends, as the parasites also continue to evolve. The term "Red Queen Hypothesis" is based on the character of the Red Queen in the book "Alice Through the Looking Glass" by Lewis Carroll. There, the Red Queen explains to Alice: "In this country, you have to run as fast as you can if you want to stay in the same place."

4. Tangled Bank*hypothesis*
*At the heart of this hypothesis is the idea that sexual reproduction creates genetic diversity that helps reduce competition between offspring. In resource-limited environments, siblings who are genetically different can exploit different niches or resources, thereby increasing overall survival chances. The term*tangled bank *refers to a quote by Darwin in his book*Origin of Species*, in which he describes the complexity of an ecosystem (in the original quote Darwin uses the synonymous term* entangled bank*).*

5. Bet hedging*hypothesis*
This hypothesis states that sexual reproduction is a strategy for organisms living in unpredictable environments. By producing genetically different offspring, sexual reproduction increases the probability that at least some of them will survive under the changing conditions. The term hedging*originally comes from the financial world and describes the strategy of hedging investments against risks.*

The fact that two individuals have to come together for sexual reproduction brings with it significant problems. The search for a suitable partner costs time and energy, which is then not available for the production of offspring. But even more problematic is that only one partner produces offspring and the other only provides the sperm. Based on this effect alone, species that do not use sexual reproduction should have a twofold fitness advantage – because they can produce twice as many offspring. This problem is known as*two-fold cost of sex.* Since Maynard Smith introduced it in his 1978 book "*The Evolution of Sex*" [5], many evolutionary biologists have been inspired to find explanations for it. Accordingly, there are many theories on this (box "Theories to solve the "*two-fold cost of sex*" Problem). At present, a pluralistic approach seems to be the most promising, i.e. not only considering a single factor to explain the problem, but assuming an interaction of several factors [6].

However, all of these theories have one thing in common: they assume variability between individuals, on the basis of which evolutionary processes can only take effect. But this variability must first be generated. Sexual reproduction is the most efficient process for this, as it involves recombination of the genetic variants of the parents in each new generation.

IN SHORT

- *Sexual reproduction is a mechanism for the* ***generation of genetic variability****as a prerequisite for evolutionary adaptations.*
- *The phenotype and behavior of the sexes is determined by****polygenic mechanisms****, which are characterized by overlapping distributions and interaction with the environment.*
- Gender*Characteristics and sexual fluidity are a* ***reflection of genetic and environmental variability****.*
- *A categorization of genders* ***does not properly reflect the variability****of individuals*

No matter which factor the *"two-fold cost of sex"* may be the best way to explain the problem, the key ultimately lies in the variability between the individuals. The fundamental function of sexual reproduction is not simply to produce offspring (this would be much more efficient through asexual reproduction), but to generate variability between offspring through recombination. But it sounds a bit circular to say that sexual reproduction is necessary to solve the evolutionary problem of sexual reproduction. So there must be another starting point for the emergence of sexual reproduction.

The Origin of Sexual Reproduction

The recombination of genetic material has been a decisive factor in evolution since the beginning of life. Without recombination, i.e. with strictly asexual cell division and reproduction, harmful mutations accumulate in the clonal lines. Since the mutation process is random, these cannot simply be reversed by reverse mutations. It is very unlikely that the same nucleotide in the genetic material will return to its original state through a further mutation. The increasing accumulation of harmful mutations would therefore lead to the extinction of the lines. This effect is now known as *"Muller's ratchet"* (see box "Theories for solving the *"two-fold cost of sex"* Problem"). This effect can only be counteracted if genetic material is exchanged between the lines that does not yet carry a mutation at the relevant points in the genome. The populations of the lines must therefore find a way to correct each other by exchanging genetic material - otherwise evolution will not proceed at all.

It is possible that the necessary correction originally worked simply by absorbing genetic material from the environment. It is now well known that DNA in particular survives in the environment long after the death of organisms. And we also know that this DNA can be absorbed by bacteria and incorporated into the genome via general repair mechanisms. Sophisticated mechanisms for genetic exchange can also be found in bacteria, but these work without a gamete stage. Only in eukaryotes has true sexual reproduction developed with reduction division and gamete stages.

In fact, sexual reproduction is extremely complicated. Gametes must arise from a derived cell division, since they can only have half a set of chromosomes. This form of cell division, known as meiosis, must also include a chromosome pairing mechanism in which recombination between the parental chromosomes occurs with the help of protein complexes [7]. And from these products, specialized cells must then arise that resemble which can fuse to form a diploid cell. The crucial point is that they must not fuse with themselves, as this would prevent the genetic material from mixing. All of these steps involve a large number of gene functions that must have been coordinated with one another and optimized through evolution. We will hardly be able to reconstruct how this happened in detail today. But there can be no doubt that these mechanisms only came at the end of a long evolutionary development, not at the beginning. The associated increased efficiency in the generation of variability then contributed significantly to the further evolution of multicellular organisms, so that this mechanism of sexual reproduction appears to be so dominant today.

The difference in the gametes

Why are there different gamete types that can be biologically described as male and female? In many single-celled organisms (e.g. algae*Chlamydomonas*, yeasts, paramecia or ciliates) and some multicellular brown algae (e.g.*Ectocarpus*), the gametes do not differ morphologically - they are then called isogamous. However, they can be differentiated according to mating types (e.g. "plus" and "minus").

But why then have different gamete types evolved in many other species? A decisive factor probably lies in the evolution of the eukaryotic cell itself. Eukaryotes have incorporated bacterial cells into the cell as organelles (including mitochondria and chloroplasts). These organelles have their own evolving genome. This creates a potential for conflict within the eukaryotic cell – the organelles could follow other evolutionary "interests"[1] than the nuclear genome. The evolutionary solution to this was to limit the recombination possibilities of the organelles through uniparental inheritance. If only one of the two gametes passes on the organelles, the organelles lose the advantage of recombination between the lines. This means that they are subject to the "*Muller's ratchet*"Problem, but since they are always present in multiple copies within eukaryotic cells, they can circumvent this problem by DNA exchange within the cell lines.

This primordial conflict within the eukaryotic cells is probably the starting point for the increasing specialization of the two gamete types, starting from isogamous precursors [8].

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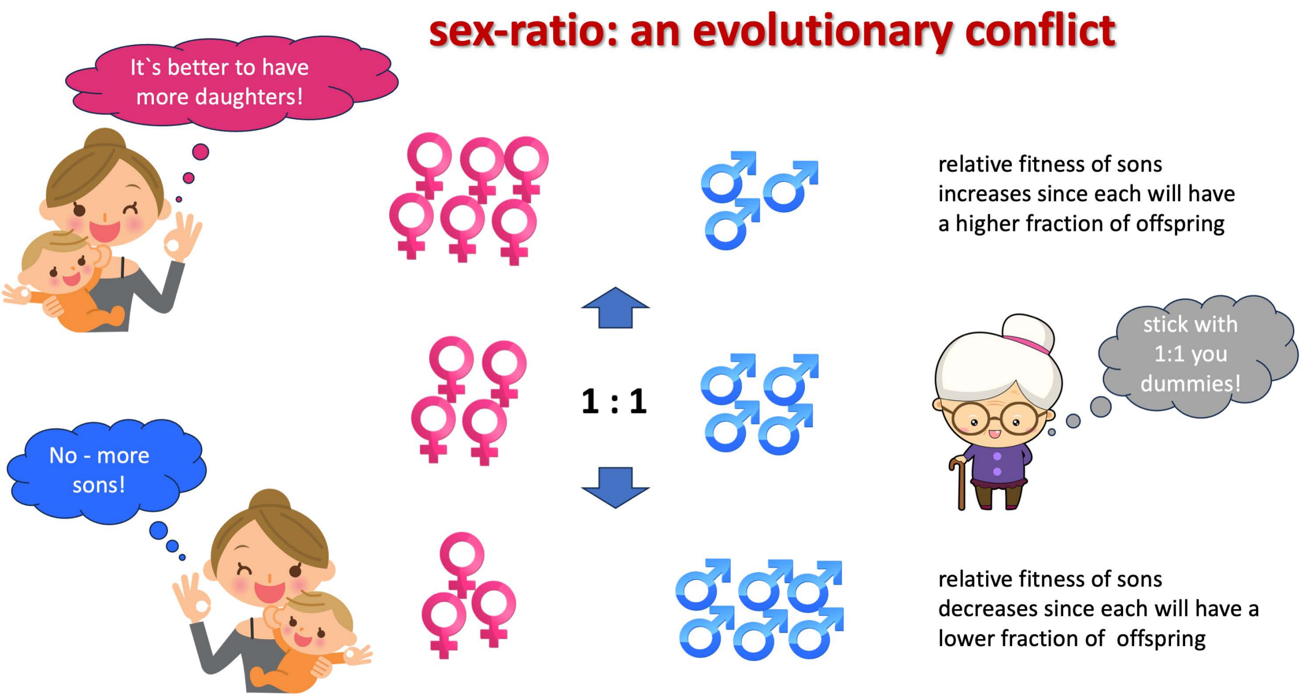
[1] Of course, organelles have no consciousness and therefore cannot have active interests. What is meant is that under certain conditions they can have a different selective advantage than their host cells, so that the evolutionary optimizations could be conflict with each other. Here (and elsewhere in the text), however, a simplified language is used for the sake of readability, which is usually used in this form among evolutionary biologists.

FIG. 1 | **EVOLUTIONARY CONFL ICT RELATED TO SEXUAL REPRODUCTION**



The illustration should be viewed from top to bottom and then from left to right. Further explanations in the text. Pictograms: open source from https://freepngimg.com and https://de.freepik.com/

The gametes (eggs) pass on the organelles (mitochondria in animals) to the offspring and at the same time prevent the penetration of mitochondria, which are brought by the male gametes (sperm). To achieve this, complicated gene systems are necessary, which also had to evolve first. The system is not perfect either - occasionally mitochondria still penetrate via the sperm, which can then displace the maternal mitochondria, which occurs more frequently in isogamous algae [9].

The apparently clear evolutionary division of roles into male and female, which appears to be determined by the gametes, is ultimately a remnant of the history of the development of eukaryotic cells. Disruptive selection processes may also have played a role in the formation of the two different gamete types in anisogamous systems [8]. The original necessity to ensure recombination between evolutionary lines gave rise to a very complex system with two sexes.

The Conflict of the Sexes

The existence of two sexes is not an optimal state from an evolutionary perspective. Although it has optimized the generation of genetic variability, many new evolutionary conflicts also arose, which continue to lead to further evolutionary steps up to today. This means that there is a great deal of evolutionary fluidity surrounding sexual reproduction, in which new solutions are constantly being found for different species. In particular, it is not possible to define "natural" evolutionary gender roles, since the only natural thing about them is that they are constantly changing in an evolutionary sense.

One of the most obvious evolutionary conflicts is the normal 50/50 distribution of the sexes in the populations of most species, including humans. If it is necessary to have two sexes, it would actually make sense that the female sex, which produces the offspring, should be more common than the male sex, which only provides the sperm (Figure 1). Males are ultimately only taking away from the females the ecological resources they need to raise the offspring. In fact, in many species there are dominance hierarchies in which males try to monopolize access to females in direct competition with other males, i.e. many of the males in the population have no offspring at all. But this means that successful males have a special fitness advantage. It is therefore "worthwhile" for females to produce more sons, since there may be one among them who has this high fitness advantage. However, this would lead to a surplus of males and the potential fitness advantage would increasingly disappear as competition becomes ever greater. The same argument also applies when there is no dominance hierarchy, for example in species with pair bonds. As soon as there is a shift in the sex ratio, the relative fitness of the more common sex changes and the system returns to a 1:1 ratio [10].

The “permanent” solution to such an evolutionary conflict (in this case the continuous shifting of the sex ratio among the offspring) does not lie in a single final solution, but in a continuous process that must be repeated again and again. Such evolutionary conflicts take place on many levels, particularly between the sexes (box “Evolutionary conflicts in sexual reproduction”), but also, for example, in the co-evolution of hosts and parasites. They are characterized by the fact that a continuous evolution of the underlying genetic mechanisms is necessary in order to remain in the optimal state (see “Red Queen” hypothesis in box “Theories for solving the problem”). *two-fold cost of sex* ”Problem”). And this is precisely why genetic variability between individuals must be continually secured.

The phenotypic difference

Let's take a look at the phenotypic differences between the sexes and within the sexes – let's stick with humans, because we can judge that best intuitively. When you meet someone on the street, you can usually classify them as male or female. But you can also usually decide whether you know the person or not. Because apart from identical twins, no two individuals are the same. That is precisely the function of sexual recombination: it is supposed to create phenotype distributions, not identical individuals – and therefore not individuals who can only be divided into two classes. Our brain therefore makes a decision that is actually schizophrenic: it classifies in a binary way based on a categorization, but at the same time recognizes that the phenotype of the individuals is very variable.

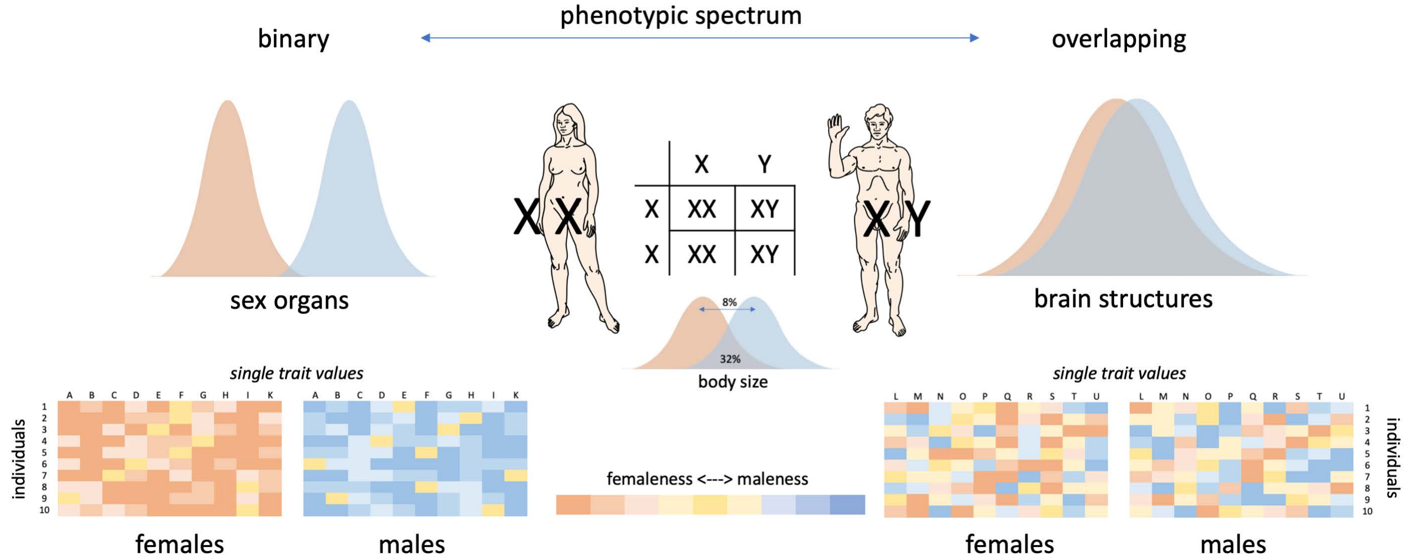
The term phenotype can encompass a great deal. This includes morphology, in relation to the sexes the development of primary and secondary sexual characteristics, but also all other aspects of an individual's external appearance. This includes physiology, i.e. physical performance, hormone balance, nutritional utilization and the immune system, and finally behavior - for the sexes, this primarily includes sexual behavior, but also all other sociobiologically relevant aspects of behavior, such as behavior based on learned cultural influences.

The phenotype of individuals arises from a cascade of genetically controlled developmental biological processes. In mammals, including humans, normal development after the fusion of the gametes leads to a female phenotype. Only at the stage in which the gonads form in the embryo (in humans in the 6th to 7th week of pregnancy) does a gene on the male sex chromosome (Y chromosome) become active to switch to a male phenotype. In most mammals, this is the so-called SRY gene (*sex region on the Y*). If this gene is defective, the body develops in a female manner, even in individuals with a Y chromosome. SRY encodes a transcription factor of the SOX class. This binds to the DNA and triggers a cascade of regulatory processes that lead to the development of testes and, via their hormone production, to the male phenotype. SRY can therefore be viewed as a binary switch. Its activity is linked to the Y chromosome and is therefore inherited according to Mendelian rules (Figure 2). Strictly speaking, this switch is the only truly binary phase of life for individuals. One could therefore define “male” and “female” independently of the gametes as SRY^+ and SRY^- (although other species also have other such switch genes). All other genetic processes that lead to the formation of the phenotype are no longer binary, but are subject to the rules of polygenic inheritance.

Polygenic inheritance differs from Mendelian inheritance in important aspects. Instead of categorical phenotypes, it produces phenotypic distributions (Figure 2). When a phenotype is under selection, the means of the distributions shift. Since the sexes are subject to divergent selection pressures, this means that they differ in the means of two distributions, one male and one female. The easiest way to see this is to look at height. In humans, men are on average eight percent taller than women, but the two distributions overlap by 32 percent. Statistically, such overlaps mean that sex explains part of the data, but does not account for the difference between the sexes per se [11].

Depending on the extent of the overlap, it is not easy to determine whether a given individual is a man or a woman by looking at a single phenotypic characteristic. The easiest way to do this is, of course, to look at the primary sexual organs. For most individuals, one can deduce the gamete type from their external appearance. However, variations and overlaps are well known at this level too. For example, the Chinese doctor Li Shizhen (1518–1593) distinguished in what was then the world's most comprehensive encyclopedia on nature and medicine *Ben cao gang mu*

FIG. 2 | OVERLAPPING DISTRIBUTION AND MOSAIC STRUCTURE OF SEX PHENOTYPES



The focus of the figure is the chromosomal sex determination based on the X and Y chromosomes, which are inherited according to Mendel's rules and lead to binary genotypes (XX and XY). All other phenotypic characters are determined by polygenic inheritance processes. These are characterized by variance between individuals with overlapping distributions. These can be seen as binary if they only overlap in a small area, as is the case for the sexual organs (left). On the other hand, there are the brain structures (not the size of the brain), where the overlap is almost complete (right). In between there can be all possible transitional forms with different overlaps.[11]**–here, as an example, height. The mosaic structure of the individuals is shown in the lower part of the figure. Here, ten characteristics are symbolically shown from left to right, which occur in both sexes, but can be more female or more male (symbolized by the color code spectrum). From top to bottom, ten individuals are shown with their combinatorial patterns of characteristics. In the binary case (left), the color code alone makes a separation very clear. But even here, even individuals of the same sex can consist of a mosaic of different variants. In the overlapping case (right), the mosaic composition is so complex that the systematic differences for the individual individual are almost completely eliminated.**

of 1593 not only men and women, but five additional types each, in particular among the additional male types also a type in which the body is both male and female [12].

When it comes to secondary sexual characteristics – such as the size of the breasts or the size of the waist and pelvis – the systematic differentiation between men and women is less clear. And there are almost no differences in the expression of the brain phenotype (Figure 2).

The mosaic structure of the sexes

There is a great deal of controversy surrounding gender differences in the brain – and thus implicitly in behavior. Women's brains are on average eight percent smaller than men's. In Victorian times, this fact led to the conclusion that men are naturally superior to women. Even an otherwise critical thinker like Darwin agreed with this judgment. In his book "The Descent of Man and Selection in Relation to Sex" [13], he writes: *"The main difference in the intellectual powers of the two sexes is that the man occupies a higher position in everything he undertakes than the woman when it comes to applying deep thought, reason, or imagination, or even just using his senses and his hand."* Darwin was not free from the influences of his time, although with a little research he could easily have come to a different view even then.

Since the average height of women is eight percent lower than that of men, it is actually trivial that the average brain size is also eight percent lower. The only thing that is relevant is the relationship between brain size and body size - and there are no differences there. Once this was clear, people tried for a long time to find structural differences in the brains of men and women. Individual regions were repeatedly identified that seemed to show small average differences. But it was only later that the question arose as to whether there was a systematic binary difference. This would exist if the different regions that show the average differences each showed the female variant in women and the male variant in men. But this is precisely not the case. Instead, the male and female brains are made up of a mosaic of male and female variants (Figure 2) [14]. It appears that each person has a different combination of variants. The averaged phenotypic distributions therefore overlap particularly strongly in the brain (Figure 2).

Nevertheless, there may be a slight predominance of male variants in some men and in some women there may be a slight predominance of female variants. Depending on the statistical approach, one can therefore deduce with a degree of certainty from the brain structures whether a person is a woman or a man. But for individual persons, the individual combination of variants is much more important than a general gender classification [14].

EVOLUTIONARY CONFLICTS OF SEXUAL REPRODUCTION

Sexual reproduction leads to a number of evolutionary conflicts that are the result of differing interests of individuals, genders or genes. The most important evolutionary conflicts include:

1. Sexual conflict:
Males and females may develop different strategies to maximize their reproductive success. Males may develop strategies to increase their chances of mating, while females develop strategies to maintain control over mate choice. This leads to an "arms race" between the sexes, with each sex trying to maximize control over reproductive success.

2. Resource conflict between the sexes:
In many species, females invest more in offspring (e.g. through pregnancy, egg laying or brood care), while males often invest in producing as many offspring as possible. This can lead to conflicts in which males try to force females to mate or females try to control the number of offspring in order to make the best use of their own resources.

3. Conflict within the sexes:
Conflicts can also occur within a sex. For example, males of a species may compete for access to females, which may lead to the evolution of structures designed to win this struggle (e.g. antlers in deer). Females may also compete, particularly when resources for raising offspring are scarce.

4. Genetic Conflict:
During sexual reproduction, genes from both parents are mixed. This can lead to conflicts between different gene variants within the same organism, especially if the variants from the mother and father have different "interests". One example is the conflict between mitochondria and nuclear-encoded genes. Another example is the imprinting *of genes, whereby epigenetic modification in the gametes determines whether only the maternal or only the paternal variant of the gene in question is expressed in the offspring.* Imprinting *is often interpreted as a solution to the resource conflict (see above), since, for example, in mammals the formation of the placenta is controlled by such gene systems.*

The genetic difference

Due to the evolutionary conflicts surrounding sexual reproduction, the genetic mechanisms of sex determination and the formation of the sexual phenotype are among the most rapidly evolving genetic systems. The chromosome that only occurs in one sex (the Y chromosome in humans) is subject to the "*Muller's ratchet*" effect and therefore loses the genes encoded on it over time. Most of the genes that are relevant for the development of sex differences are therefore not found on the sex chromosomes, but on the autosomes. They are expressed differently in female and male individuals in order to fulfil their specific functions in the development of the sex phenotype. This is referred to as *sex-biased expression* (*SB* Genes) and depending on the organ, several hundred to several thousand genes can show such differential expression. Only very few genes are active exclusively in one sex, most differ only in their relative expression. They are not only active in the sex organs, but in practically all organs and tissues of the body. These different expressions can now be measured very well and compared evolutionarily using genome-wide transcription analyses.

In a comparative study between different mammals, it was shown that sex-specific expression varies in different organs and species. Each organ and cell type has its own pattern of *SB* genes [15]. The mosaic principle that was found in brain morphology is also evident for all organs at the level of gene expression.

Interestingly, sex-specific expression evolves rapidly across species. Even between closely related mouse species, only less than five percent of *SB* Genes in the different organs show a conserved *SB* expression [16]. Such a rapidly evolving pattern with thousands of genes involved is only compatible with a polygenic inheritance model in which the role of individual genes in the expression of a phenotype can easily be replaced by other genes.

If one considers the individual variability of the expression of *SB* genes, one can often see overlapping distributions [16] – similar to the phenotype. The simple assumption of a male-female binarity at the level of gene expression does not apply. In particular, one can also not classify into three categories – male, female, diverse.

The Role of the Environment

Polygenic inheritance mechanisms always contain a genetic and an "environmental" component. The latter formally describes only the proportion of variation between individuals that cannot be attributed to genetic factors. It is usually not possible to say exactly what this "environmental" component is. It can be the general environmental conditions such as temperature and nutrition, but it can also be epigenetic effects (e.g. methylation of DNA, histones or RNA, alternative *splicing* or microRNA concentrations), but also a learned or cultural influence - especially in behavior. The genetic component of polygenic inheritance is called "heritability". The measurement of heritability depends on the experimental conditions. If the environmental conditions are kept as constant as possible, high heritability values result for most phenotypic characters. If the environment is very variable, the proportion of heritability is reduced. In humans, the environment will usually be very variable; the extent of the phenotypic variance will therefore be greater, and the relative role of genetic variance will be smaller. This of course also applies to the variance between the gender phenotypes and sexual behavior. A strong cultural influence on these parts of the phenotype is therefore to be expected, but there will always be a genetic component at the same time, which can be expressed to varying degrees in different individuals.

With regard to behavioral differences in humans, one can also refer back to the book by Li Shizhen (see above). There, three behavioral groups are distinguished with behavior that deviates from the norm. Those who are supposed to behave like men but act like women. Those who are supposed to behave like women but act like men. And those who are Yin/female in one half of the month and Yang/male in the other half of the month. Fluidity in sexual behavior has therefore always existed in humans.

The Trap of Categories

When considering genetic and environmental variability, a simple binary categorisation into male and female does not do justice to the phenotypic reality of individuals. Sex researchers and psychologists have long known this, which is why the term *Gender* for the felt and/or social gender identity, is contrasted to the biological sex determination.

However, there is a tendency to view biological sex determination separately from gender characteristics. The one is considered binary and biological, the other purely culturally developed. But this is ultimately also an inappropriate categorization.

The metaphorical statement "Women are from Venus, men are from Mars" has a biological basis in the evolutionary conflict between male and female interests. Sexual conflicts are ubiquitous and encompass processes from partner choice to parental investment in offspring (see box "Evolutionary conflicts of sexual reproduction"). Sexual conflicts potentially ensure that each sex tries to achieve its preferred optimum for a particular "conflict trait" [17].

There are undoubtedly "typical" men and women and "typical" female and male behavior that can be traced back to this conflict between the sexes and that is ultimately also genetically anchored. But it is not a categorically binary behavior that can be assigned to an individual. What is referred to as "typical" are averages or even extreme values of two overlapping distributions. The individuals themselves are mosaics of characteristics that recombine in each generation. The evolutionary conflict between the sexes has no final solution, but is constantly re-emerging [17]. In particular, in the area of overlap of characteristics, there must also be a fluidity between the "typical" characteristics in order to enable continuous evolution to resolve the ongoing conflict. Gender fluidity is therefore not only a natural phenomenon, but even an inevitable consequence of sexual reproduction.

The development of biological, genetic and cultural gender identity must be viewed as an overall process that should not be put into categories - including extended gender categories. Each individual must be seen for themselves and each individual should therefore be allowed to find their own role in the continuous spectrum of distributions. No individual should feel pressured to conform to the social norm of a category. Individuals should not be reduced to their gametes; the evolutionary and developmental biological reality is much more complex. In particular, gender-fluidic individuals should not be viewed as an exception to a rule, but as a natural part of the evolutionarily necessary variability within populations.

This does not only apply to humans. It is also a general biological principle. Individuals are genetically variable by nature, but are also shaped by the environment in which they grew up. If one wants to categorize them based on experimental operational criteria, as is often the case in behavioral research, then it would be important to also indicate the degrees of overlap for the morphological characters or behaviors under consideration and to take these into account in the interpretation of the results. This is not an anthropocentric view, but the conclusion from considerations on the evolution of sexual systems.

An alternative narrative

In biology classes, the explanation of sexuality usually begins with a description of two sexes that are defined by their gametes. Binary therefore appears to be a basic biological state in which a category of "diverse" is seen only as an exception.

But one could also base the teaching on the biological role of sexuality, that is, on the evolutionary-biological necessity of generating variability. Then the teaching on the origin of sexuality would begin with the explanation that variability is at the core of life. This interpretation of sexuality was already proposed by August Weismann. In his 1886 book "The Significance of Sexual Reproduction for the Theory of Selection" [18] he writes: *"In this mixture I see the cause of hereditary individual characters and in the production of these characters the task of [sexual] reproduction."*. (p. 29) and *"In general, I cannot attribute any other significance to sexual reproduction than that of creating the material of hereditary individual characters with which selection can work."*(p. 43)

These are key statements that one could base a class teaching on. The existence of two sexes is then explained as a biological mechanism to ensure this variability. The primary role of men and women is therefore to have offspring that are different from themselves and also different from each other. "Diverse" is then no longer an exception, but part of the natural spectrum of variability. As biologists, we should keep in mind the Darwin quote above. One can be completely trapped in the dominant way of thinking, even if it is possible to see the alternatives.

What does the new law say?

Against this background, the progress that the new legislation on sexual self-determination is supposed to achieve is actually a step backwards. Instead of completely abolishing the official registration of gender categories, another category is introduced, combined with freedom of choice. In fact, this is then an obligation to choose, since ultimately every individual has to ask themselves at some point which category they belong to. One is pressured to take a side, even if one is not really sure where exactly one stands on the continuous spectrum. The fact that the category "diverse" exists is of little help, or even counterproductive. Every kind of categorization can lead to new discrimination – and the risk is even higher with three categories than with two.

In its 2017 ruling, the Constitutional Court actually gave the legislature the freedom to abolish the registration of gender categories altogether (paragraph 65 in [3]). This is because, with constitutionally guaranteed gender equality, the state no longer needs to know which gender someone feels to belong to.

This would of course not lead to the abolition of genders. After all, nobody looks in the civil register beforehand to find a sexual partner anyway. I also cannot see any concern that such a step would undermine efforts to achieve equality measures. On the contrary: what would happen if men registered as women in order to be able to apply for equality programs intended for women? The general phenotype would then of course be used as the admission criterion, not the entry in the civil register. But that would then lead to new legal problems.

When revising the law, the legislator missed the opportunity to send a signal that the binary classification of genders does not do justice to the reality of individuals. But our deeply rooted categorizing way of thinking clearly lacked the courage to do so. When will we start thinking in terms of continuous distributions and their overlaps instead of categories?

Summary

Female – male – diverse: Is it that simple?

The evolution of bisexual reproduction is the driving force behind evolution, as it generates the variability between individuals that is necessary for adaptation. Compared to asexual reproduction, however, it has the disadvantage that it only produces half as many offspring. It also leads to evolutionary conflicts between the sexes. These disadvantages can only be outweighed by the advantage of producing particularly high variability. Therefore, individuals arising from sexual reproduction show overlapping morphological characteristics and behavioral patterns, which are also influenced by the environment. Fluidity between the sexes is thus a natural consequence of this variability. This continuum of differences is not reflected by a categorization into "male – female – diverse".

Tags:
Law of self-determination, evolution of sexual reproduction, evolutionary conflict, *two-fold cost of sex*, *Muller's ratchet*, fluidity of the sexes, gender, mosaic structure of the sex phenotypes, gametes, isogamy, anisogamy, variability, heritability, polygenic inheritance

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