



## HAVING BABIES IN SOIL: IS SEX REALLY NECESSARY?

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### YOUNG REVIEWERS:



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AGE: 12

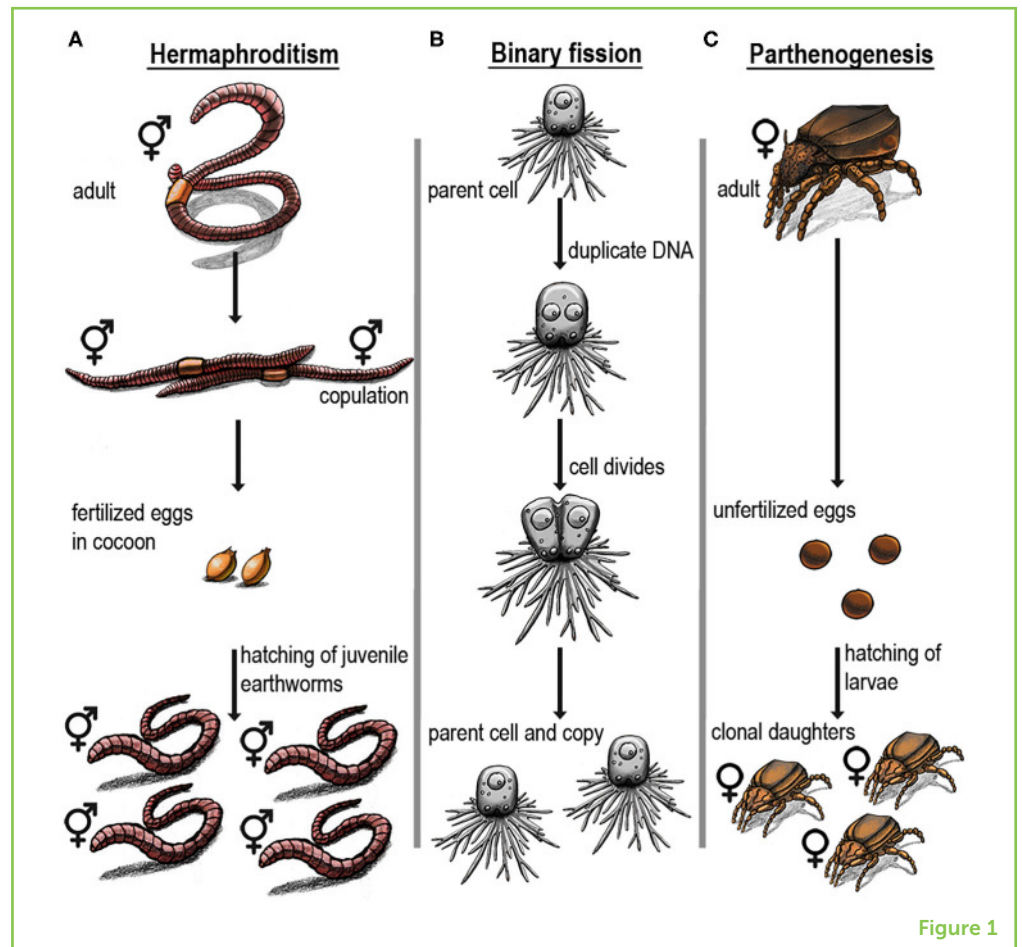


**VALERIE**  
AGE: 13

Finding a partner and having sex to produce babies is a common way to reproduce. Yet, upon closer look, we see that nature provides many ways for reproduction. What about a world without males? What first sounds impossible is the reality for many organisms that reproduce asexually, meaning without having sex. Females produce daughters that are clones of themselves, so no partner is required and males are dispensable. An Example of such all-female societies are several species of oribatid mites, which live in soils. These mites were already on earth long before the dinosaurs. Have oribatid mites always been asexual? Why do they reproduce without males? Does asexual reproduction have any advantages? Keep reading to learn about asexual reproduction and why oribatid mites are a key organism to investigate the question, "Why sex?"

**Figure 1**

Overview of different reproductive modes described in the text. **(A)** In hermaphroditism, each individual possesses both male and female reproductive organs; earthworms fertilize each other and each individual lays eggs. **(B)** In binary fission, a cell divides into two cells of equal size after duplicating its genetic material. Two individuals are produced from a single parent cell. This method is used by many Protists, for example amoebae. **(C)** Parthenogenesis is a form of asexual reproduction in which an offspring develops from an unfertilized egg cell. Some oribatid mites reproduce via parthenogenesis.

**Figure 1**

## SEXUAL REPRODUCTION

Reproductive mode that requires an egg cell of a female and sperm cell of a male individual. The offspring is a unique individual that carries half of each parent's DNA.

## ZYGOTE

A cell resulting from the fusion of a male's sperm cell with a female's egg cell i.e., a zygote is a fertilized egg.

## HERMAPHRODITE

A single individual that can produce both egg cells and sperm cells. It is basically both a female and a male.

## REPRODUCTION IN SOIL ORGANISMS

All living organisms reproduce to generate new offspring. Almost all organisms, including humans, use some form of sex to reproduce. In **sexual reproduction**, an egg cell produced by a female and a sperm cell produced by a male fuse. The result is a **zygote** that develops into a unique offspring. Each offspring is a mixture of its parents, since it inherits half of its DNA from its mother and half from its father. The new offspring grows, becomes an adult, finds a partner, and finally produces offspring itself. This is the circle of life.

Many kinds of organisms live in soil, and they have a variety of different ways to reproduce. For example, earthworms are **hermaphrodites**, which means that one worm has both male and female reproductive organs. Earthworms reproduce sexually—if two earthworms meet, they exchange sperm cells that fuse with the egg cells of the other earthworm (Figure 1A). Since they have both male and female sex organs, earthworms do not have to worry about finding a partner of the opposite sex because there is always a match. Earthworms belong to a group of soil organisms called the macrofauna, which includes all animals larger than 2 mm. Macrofauna are soil giants compared to most soil organisms.

## PROTIST

Single celled organism that are eukaryotes. Many feed on bacteria and release excess nitrogen, providing essential nutrients for plants and other organisms.

## ASEXUAL REPRODUCTION

Any type of reproductive mode that produces offspring without the fusion of egg and sperm cells, also called gametes. The offspring are identical to the parent and/or to each other.

## BINARY FISSION

A cell divides into two cells of equal size after duplicating its genetic material. Two individuals are produced from a single parent cell i.e., one daughter and one parent cell.

## PARTHENOGENESIS

A form of asexual reproduction in which an offspring develops from an unfertilized egg cell.

## EUKARYOTES

Can be animals, plants, single-celled organisms like protists and fungi. These are complex cells, where the genetic information is organized in a nucleus.

The greatest number of soil organisms belongs to the microfauna, which consists of organisms smaller than 0.1 mm. Most are single-celled organisms called **protists**. They are so small that one handful of soil contains more protists than there are humans in the entire world. For reproduction, protists do not need a partner at all. Some protists reproduce via a type of **asexual reproduction**, by making exact copies of themselves through a process called **binary fission**. First, they duplicate all their genetic material, and then one cell divides in two (Figure 1B). If repeated several times, many identical copies of one individual independently populate the soil.

Another essential group of soil organisms is known as the mesofauna, which includes all soil animals between 0.1 and 2 millimeters in size. The soil mesofauna includes springtails and oribatid mites. These organisms are very common and play a key role in the soil food web. They shred dead organic matter from plants, making the nutrients available to other organisms, including bacteria and fungi, which are then eaten by other belowground organisms. Many oribatid mites live in all-female populations and have done so for millions of years. They do not need sex for reproduction, because they can lay eggs that develop without being fertilized by a male, in a process called **parthenogenesis** (Figure 1C). Each egg contains the DNA only of the mother, which means that the offspring are clones of the mother.

## ADVANTAGES OF ASEXUAL REPRODUCTION

Copying or cloning oneself seems to be much easier than finding a partner, but there are even more advantages of asexual reproduction. If you follow a sexual and an asexual population over time, two major differences appear. An asexual female only produces daughters, and these daughters produce only daughters again when *they* reproduce. The sexual females, however, must produce sons to fertilize the eggs—but only daughters can produce offspring. So, even if sexual and asexual females produce the same number of offspring, the asexual female has more daughters, which means more offspring that can reproduce.

Over time, the asexual population grows much faster and may outcompete the sexual population just by numbers (Figure 2). Scientists call this the “cost of males.” In addition to providing greater population growth, asexual reproduction seems to have other advantages: no sexually transmitted diseases, no energy loss, and no chance of being eaten by predators while trying to find a mate.

## WHAT IS THE USE OF SEX IF REPRODUCTION CAN HAPPEN WITHOUT IT?

If there are successful ways of asexual reproduction, why do **eukaryotes** bother with complex, risky, and costly sexual reproduction?

## Figure 2

Predicted population growth for sexual and asexual populations. In this example, each female produces two offspring. The size of the sexually reproducing population remains constant over time, because males are needed to fertilize the eggs of the females, but they cannot have offspring themselves. In asexual reproduction, the female produces twice as many childbearing offspring (females), leading to exponential population growth. (F0: parental generation, F1: first set of offspring from parents, F2: next generation of offspring from F1).

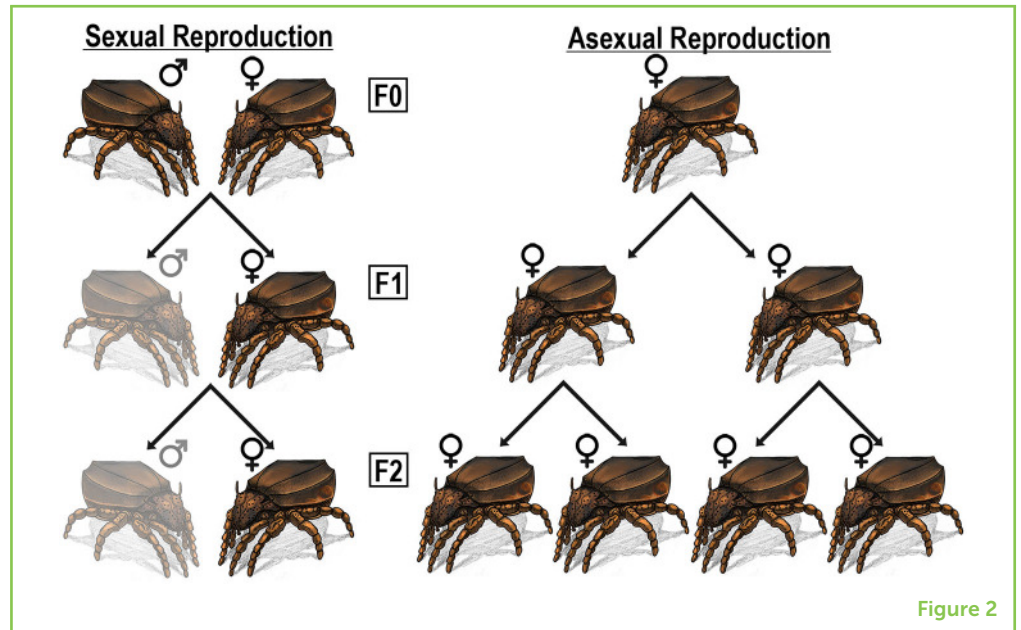


Figure 2

More than 98% of all animals use sex to reproduce. This means that sexual reproduction must have clear advantages over asexual reproduction. Therefore, scientists try to explain the benefits of sex mainly by looking for potential problems if sex is not used. One disadvantage that scientists proposed for asexual reproduction has to do with mutations. Mutations are changes in the DNA that are an important cause of diversity among organisms. Occasionally, mutations are beneficial—sometimes they are very harmful—and most of the time they are slightly harmful. When an organism copies itself all the time, slightly harmful mutations keep adding up over generations, causing more and more harm. Once they build up enough, these mutations could lead to the extinction of the species. This does not happen in sexual organisms, because the harmful mutations of one parent can be compensated for by the unmutated DNA from the other parent. Think of two bikes, one with a flat tire and one with a broken pedal. By combining parts from the two, you could still have a functional bike. It would be preferable to have one fully functional instead of two semi-functional ones. Some scientists suggest that this repair mechanism is an essential advantage of sexual over asexual reproduction.

Furthermore, just making copies or clones means that an organism will stay the same for many generations. This leads to problems when the environment changes. For example, the availability of resources such as food could change over time, e.g., due to climate change or the presence of other organisms competing for food. Food may develop a defense strategy, like running faster or becoming poisonous. Parasites can also be a problem. Since all individuals in an asexual population are very similar, they will not have the tiny differences that could help them adapt quickly enough to the ever-changing environment, so they would eventually die out. This means that offspring produced through

sexual reproduction have higher chances of survival simply because they are different from those that came before them. This seems to tell us that all asexual organisms should go extinct in the long term. But, knowing that so many asexual organisms thrive in soil, we asked whether asexual organisms truly are doomed to die.

## GENES CAN TELL US ABOUT ASEXUAL REPRODUCTION

Our research groups work with soil-living oribatid mites because many asexual species have survived without males for millions of years. We analyze the genes of sexual and asexual oribatid mite species because genes can tell us what happened to organisms in the past. Imagine genes as a captain's logbook, in which important things that happened to an organism in the past were recorded and passed on to future generations. We are still able to see the disadvantages of asexual reproduction in these logbooks. If we compare logbooks of oribatid mites that reproduce sexually to those that reproduce asexually, we can figure out which of the above-mentioned problems occurred and how they were solved. Since we are comparing two very similar species of mites, most of the genes are very similar. However, for some genes we can identify certain differences that must be caused by the consequences of the different reproductive modes.

In contrast to what scientists theorized, we found that asexual species do *not* accumulate more harmful mutations than sexual species (Figure 3) [1]. They do not need to combine two broken bikes to get a functional bike, because they keep the bikes functional. We also found that the asexual mites *do* maintain variability in their large populations [2]. The genes in separate mother-daughter lines are as different from each other as are individuals that mix genes by reproducing sexually. Last, we found that the genes of two (or more) populations of asexual oribatid mites can be as varied as the genes of sexual species. This means that asexual oribatid mites *do not* stay the same for many generations, so they *can* adapt to new environments and are even able to diverge into new species [3].

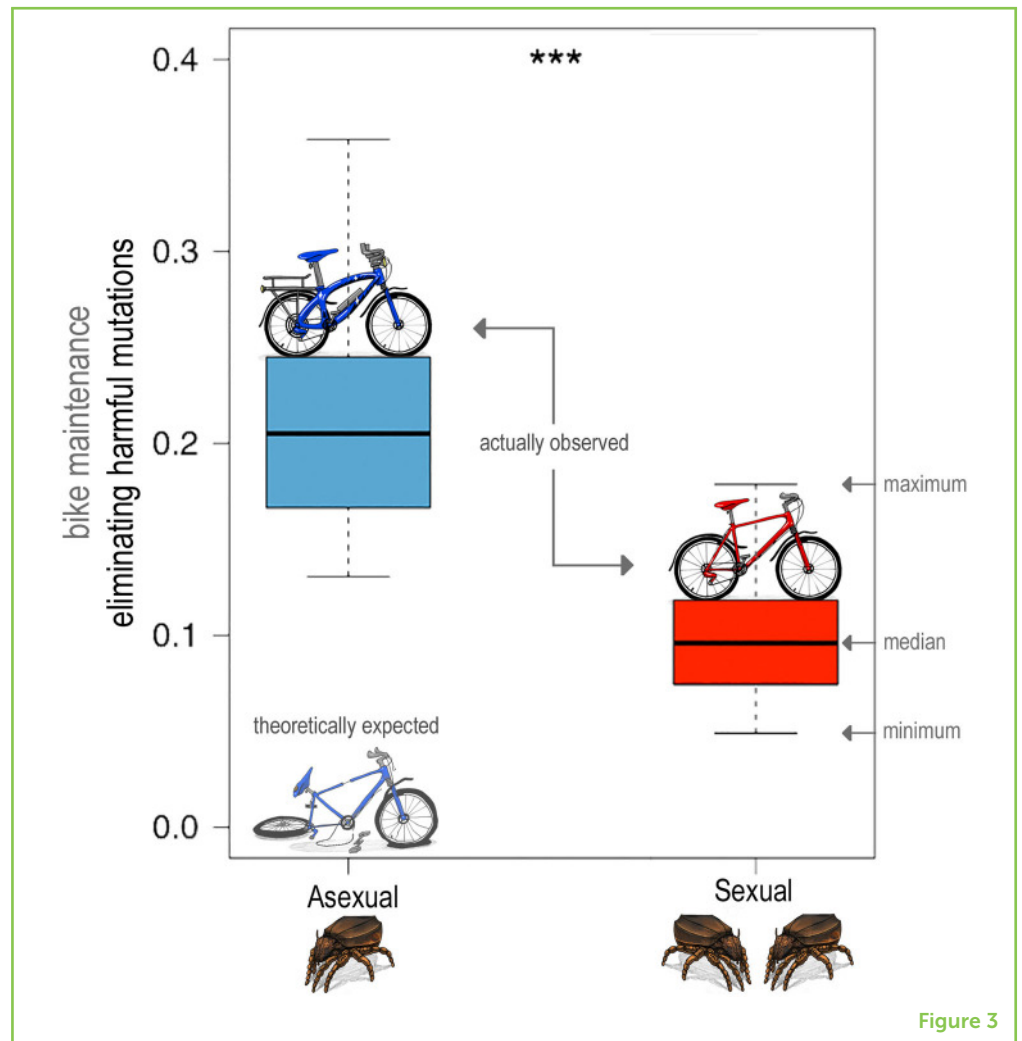
From our research, it appears that asexual oribatid mites have no disadvantages compared with the ones that reproduce sexually. They keep mutations in check, maintain genetic variability, and adapt over time, all without sex!

## WHY IS THIS IMPORTANT?

There are many ways to produce offspring, and they do not always include sex. In theory, asexual species are expected to go extinct. In nature, however, there are various asexual organisms that have persisted over time. There must be ways to overcome the disadvantages of asexuality, as we saw in the asexual oribatid mites.

### Figure 3

Asexual oribatid mites get rid of slightly harmful mutations even more effectively than sexual oribatid mites [1]. Asexuals are even better at maintaining healthy genes (indicated by the fancy blue bike) than the sexual species (which still have decent red bikes). A boxplot shows the middle 50% of the data, each with a line in the middle representing the median (center of data). The two lines outside the box indicate the highest (maximum) and lowest (minimum) observations. The three stars on top indicate that this result is statistically significant, meaning it is very unlikely to observe this just by chance.



But how do they do it? Do they have special mechanisms that fix mutations? Do they have to maintain a large population size to keep genetic variability? Is it easier to be asexual if you feed on a dead food source, which cannot develop defense strategies that you must adapt to? One future challenge will be to find the mechanisms that most asexual organisms have in common. Scientists continue to work on pairs of related sexual and asexual organisms to shed light on the variety of reproduction modes and to attempt to answer the question, "Why is sex so common?"

### ACKNOWLEDGMENTS

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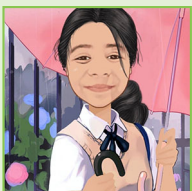
### DARIO, AGE: 14

My name is Dario. I live in a small village in Austria. It is full of nature so in my freetime I like to go out with my dogs or climb trees. My parents are both biologist so I got into biology pretty early.



### LUVENA, AGE: 11

Hi, my name is Luvena! I love music, sports, and food. My favorite subjects in school are math and language arts. In my spare time, I enjoy playing piano and reading books with my sister. When I grow up, I would like to be a neurosurgeon.



### PRANATEE, AGE: 12

Hello! I love to bake, especially tarts and pies. In school, my favorite subjects are science, lunch, and recess. I like spending time outdoors and going hiking. I also love going to the beach and have an interest in photography. Watching my favorite TV shows, painting, listening to music, singing, and hanging out with friends are my



favorite things to do in my free time. In the future, I would like to either like to be a scientist, or a singer/songwriter and actress.



### VALERIE, AGE: 13

I am in 8th grade of a middle school in Austria. My hobbies are horsebackriding, skating, and dancing. I have got a very old cat and we are getting a dog soon. I also like meeting my friends and listening to some music.

## AUTHORS

### HÜSNA ÖZTOPRAK

At first, I studied biology to become a scientific journalist. During my studies I quickly realized I want to find answers to my own question, so I became a researcher. During my master's research I found and described new species of testate amoebae. I became interested in how asexual organisms diverge into new species. So, I started my Ph.D. at the University of Cologne, Germany. I like to travel and try new foods. At the moment, staying at home is the responsible thing to do. So, when I am not in the lab, I stay in and binge-watch anime. \*h.oeztoprak@uni-koeln.de



### ALEXANDER BRANDT

I am an evolutionary biologist at the University of Lausanne in Switzerland. In my research I mostly analyze genes using the computer. However, I always enjoy watching (soil) animals (under the microscope) when I have some free time in the lab. I spent a lot of time comparing how many harmful mutations have accumulated in asexual and sexual oribatid mites during their evolution. For this work, I just recently obtained my Ph.D. from the University of Göttingen (about which I am really proud)! In my free time I like watching documentaries about dinosaurs, meeting friends, and I play drums in a rock band.



### MARCEL D. SOLBACH

I am a biology Ph.D. student from Cologne. I conducted work on various microorganisms including microalgae, intracellular bacteria in amoebae, and currently on protists as potential plant pathogens. When I am not sitting in the laboratory, I try to build a side-career as a fantasy artist and illustrator—hence I painted the pictures in this article! In my remaining time, I like to play basketball and go swimming, to prevent my aging and aching body from falling apart.



### JENS BAST

As a kid (and still as an adult), I was fascinated by animals, mostly cats. And genes. I genetically manipulated my first bacteria at 17. This is how I got into biology and when I started thinking about why the things in nature are the way they are. I use my passion for genes and animals to try to understand what happens in evolution when sex is lost. I enjoy working with other scientists so that we can solve scientific questions together. In my free time I like to cook and eat, to travel, to make music, and to play games.







### **INA SCHAEFER**

The diversity and distinctness of the natural world made me think about what we think is normal and what is unusual. This is why I became a scientist, because science is supposed to be objective. I am fascinated by the soil environment because life in soil is so different from our everyday above-ground experience in many ways. However, because I am a large and clumsy human that cannot see nor move in soil, I need to investigate the DNA of soil organisms to understand what they do and who they are.