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Why Are There So Many Mosquitoes?

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Why Are There So Many Mosquitoes?

How mosquitoes went from phoretic and pollinating symbionts to pathogenic and parasitic vectors.

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Abstract

Mosquitoes have been challenging man and animals alike since the fall. Mosquitoes number in the trillions worldwide. Not only is the mosquito a nuisance with the constant buzz around your ear, they also are the primary vector of many dangerous diseases including the West Nile Virus (WNV). WNV has become a more prominent mosquito-transmitted disease in the United States and more specifically in Colorado, Texas, and other states in the Midwest. While commonly found in the genus *Culex*, WNV and other diseases can be found in different genera of mosquito, including *Aedes* and *Anopheles.* While these two are not the most common regarding WNV, they still play a significant role in the environment.

While the mosquito is typically put on the "enemy's list" for most, they do, however, play a vital role in assisting with phoresis and pollination. In fact, without the mosquito, some of our favorite plants, including the flowers known as orchids where the male counterparts of the subspecies of the *Aedes* population provide most of the pollination, would not exist. The mosquito, while sometimes a nuisance and a dangerous carrier of unwanted disease, has a significant role in the success of the environment that was implemented by the Creator.

Keywords: mosquitoes, *Aedes*, *Anopheles*, *Culex,* West Nile virus, phoresis, pollination, ecotypes, Walter Reed, parasitology, Increased standing water, infectious disease, mosquito-borne disease, public health, USA

Introduction

When Americans think of summertime, what usually comes to mind are hot dogs, fireworks, swimming pools—and bug bites. It is hard for people to leave a summer gathering without a few itchy bumps on their legs and arms. These bug bites are likely caused by mosquitoes, and according to the CDC, there are roughly 200 species of mosquitoes in the United States and territories, but only 12 of these are possible vectors of disease (CDC 2020). The most common of the twelve include the *Aedes*, *Culex*, and *Anopheles* species. The *Aedes* species is known to carry diseases such as yellow fever, dengue, and the Zika virus. The *Culex* species is known to carry West Nile virus, and the *Anopheles* species is known to carry the infamous *Plasmodium* species that leads to malaria. The type of disease/parasites they carry depends on the different physiological characteristics and geographical location of the mosquito. Thankfully, through modern medical practices, these viruses are uncommon in the United States. However, if safe practices are abandoned, mosquito-borne diseases could make a comeback.

Surprisingly, in the United States, the most frequent mosquito bites come from nuisance mosquitoes, which do not spread disease (unfortunately, they still itch!) (CDC 2020). To prevent this annoying itch, there are several easy preventative measures. For example, mosquitoes

typically lay their eggs on top of still water or marshy grounds. Therefore, mosquitoes that can be found living near people typically lay their eggs around homes in pots of water and consistent puddles. Therefore, it is best to dump any excess water and control drainage issues in and around the home. The CDC also recommends spraying repellents such as DEET and wearing long clothing to cover the skin (CDC 2020).

In this paper, we describe the good, the bad, and the ugly of mosquitoes. We include a description of the newer terminology that is being emphasized in scientific literature: *ecotypes*, which means a distinct form of an organism occupying its microhabitat. Mosquitoes are complex organisms that are often despised because of their deadly potential. However, the more that is known about mosquitoes, the more their positive qualities can be appreciated, and their harmful qualities and unfortunate reputation can be overlooked.

Phoresis

Mosquitoes are known to carry deadly parasites that lead to viruses such as malaria, Zika virus, dengue, and West Nile virus. Because of this, mosquitoes are known as parasites to mammals. However, parasitism is not the only relationship that mosquitoes form with other organisms. They also form relationships that are sometimes mutually beneficial. *Mutualism* is a relationship in which two species benefit from each other metabolically. For instance, *Plasmodium* gives mosquitoes a keener sense of smell, which allows them to find their host/food more efficiently (Carr et al. 2021). In fact, a study showed that mosquitoes were attracted to scents of flowers instead of just images of flowers (Peach and Gries, 2020). However, phoresis is perhaps the most overlooked mutualistic relationship that mosquitoes have with other organisms. *Phoresis* is defined as being a non-permanent, communalistic interaction in which one organism (a phoront or phoretic) attaches itself to another (the host) solely for the purpose of travel. What makes phoresies unique from the other symbiotic relationships is that neither organism is metabolically dependent on the other. A prime example of phoresies is mites. Most species of mites climb

aboard scavenger beetles to arrive at decaying organisms (Perotti and Braig 2009). Like these mites, mosquitoes form such relationships with flowering plants through pollination.

Fig. 1. A phoretic mite riding on a carrion beetle. Image by Sandy Rae via **Wikimedia Commons**.

Pollination

Just like other insects, mosquitoes need the high sugar content found in nectar to fully function (Peach et al. 2021). In fact, female mosquitoes are the only ones known to suck blood. Therefore, all the nutrients needed for a male to survive are found in plant juices. As the mosquito drinks the nectar with its long proboscis, the pollen tends to stick to the mosquitoes' eyes, which transfers

the pollen to the next flower (Statman-Weil 2022). Butterflies have a similar technique because they both suck nectar. However, bees pollinate flowers much differently. Bees need pollen for protein, so bees purposefully try to get as much pollen on them as possible, buzzing on a flower to shake some out of the anther (Knight 2019). Although bees are well-known pollinators, their numbers have been declining in recent years. This could be due to a condition called Colony Collapse Disorder (CCD). This occurs when most of the worker bees abandon the hive and their queen due to factors such as pollutants and pesticides (Nowierski et al. 2021). If bee populations continue to decline, then flowering plants will have to rely on other insects such as mosquitoes. Already, the US Forest Service claims that the *Aedes communis* mosquito is the most important pollinator for broad-leaf orchids, which are found in the Northeastern US and Canada.

Fig. 2. A mosquito sucking nectar from a flower. Image by Abhishek727 via **Wikimedia Commons**.

Living in a world pollinated by mosquitoes is imaginable, and it is good stewardship to preserve the creatures that **God [http://answersingenesis.org/god/]** entrusted to our care. **Genesis [http://answersingenesis.org/genesis/]** 1:24–25 states, "Then God said, 'Let the earth produce living creatures according to their kind' . . . and God saw that it was good" (NASB). If God himself thought **creation [http://answersingenesis.org/creation/]** before the curse of Genesis 3 was good, then it is important to conserve its naturality. This raises the burning question, if God thought the world was "good," then why do mosquitoes cause the deaths of thousands of people every year? The answer: mosquitoes were likely created as pollinators, then through the fall of man and gene loss, mosquitoes began to feed on humans.

Fig. 3. Artist's sketch of a broad-leafed orchid, which depends on mosquitoes for pollination. Image by Fæ via **Wikimedia Commons**.

Pathogen and Parasite Vectors

The fall of man caused a curse to be placed on all living beings, which inevitably led to some species of mosquitoes becoming parasitic and carrying pathogens, even deadly ones (**Genesis 3:14**). The three most medically important genera are *Aedes*, *Anopheles*, and *Culex* (CDC 2020). *The Aedes* mosquito, specifically *Aedes aegypti*, is known to cause diseases such as dengue virus, yellow fever, chikungunya, and Zika virus. This parasite vector has four life stages (egg, larva, pupa, and adult) and becomes parasitic at the adult stage, where the females feed on humans and animals for blood to produce eggs. Unlike most mosquitoes, they specifically favor biting humans and typically bite during the day (CDC 2022). Therefore, they prefer to live near humans and can be found in homes and other buildings that have doors and windows propped open without screens and can reproduce both inside and outside (CDC 2022).

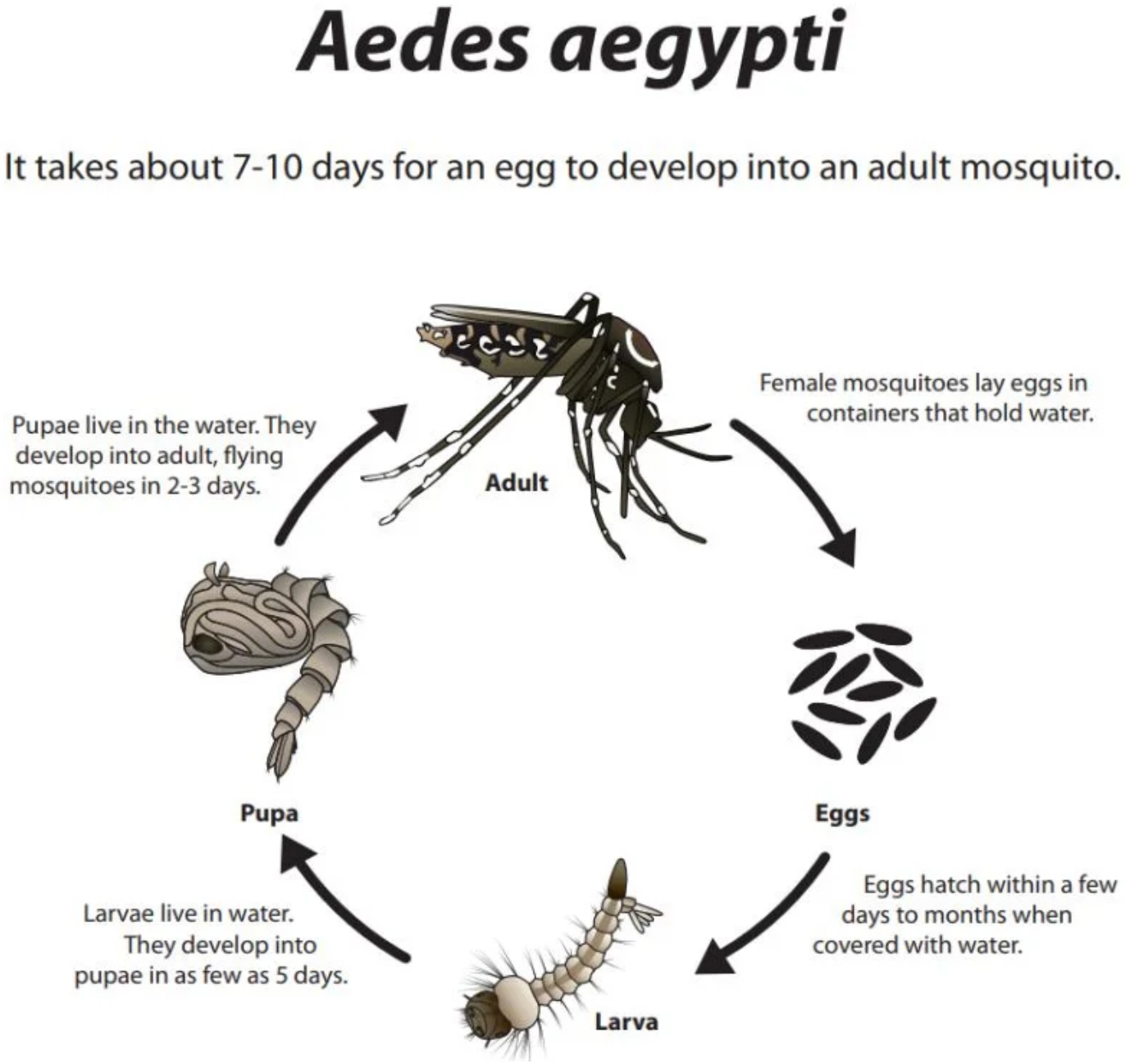

Fig. 4. Aedes aegypti life cycle as described by the **CDC**.

Female mosquitoes contract dengue virus by ingesting the blood of an infected person. For yellow fever, however, female mosquitoes get infected through feeding on infected primates as part of three different cycles:

- The sylvatic, or jungle, cycle is the transmission of a virus between non-human primates and a mosquito species found in forest canopies.

- The intermediate, or savannah, cycle involves the transmission of a virus from mosquitoes to humans (the virus can be transmitted from human to human or monkey to human through mosquitoes).
- The urban cycle encompasses the transmission of a virus between humans and mosquitoes that live in urban areas (CDC 2019). This virus is generally brought to urban areas by a viremic individual that was infected in the savannah or jungle (CDC 2019).

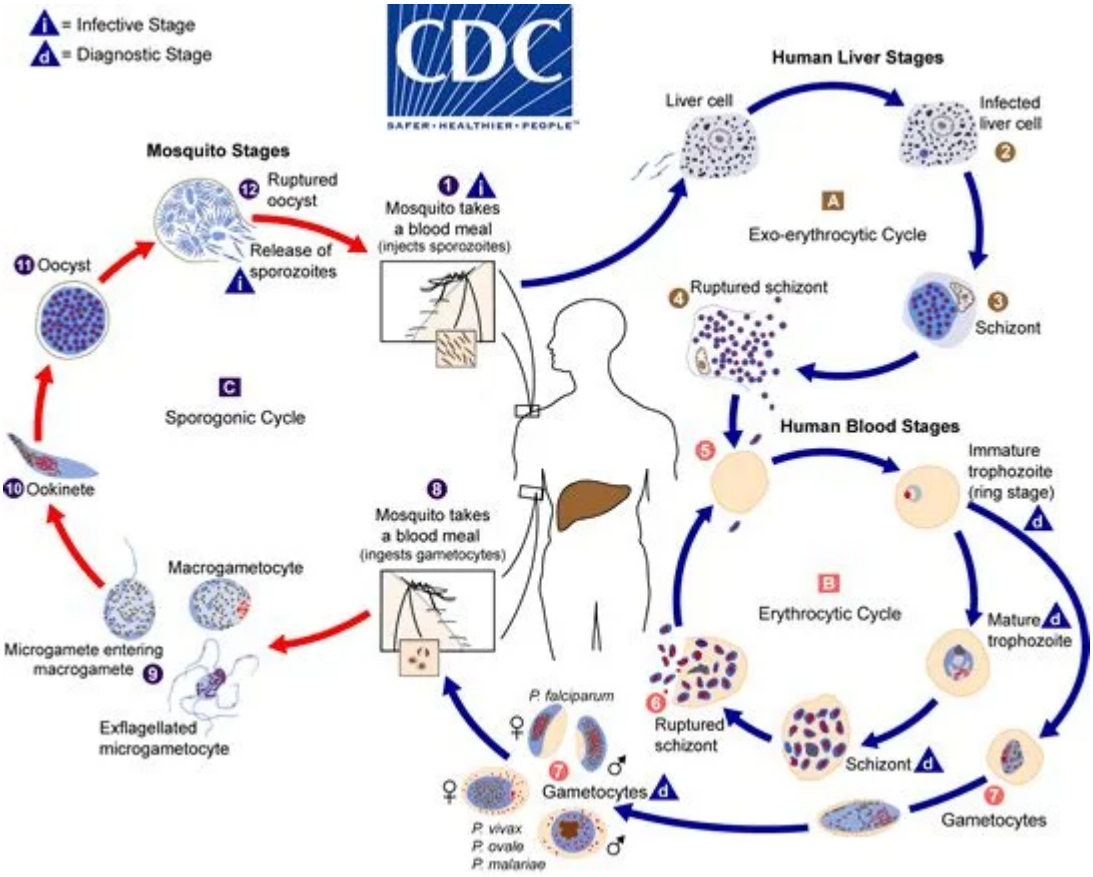

Fig. 5. Malaria Life Cycle as described by the **CDC**.

The *Anopheles* mosquito is responsible for transmitting the serious and sometimes fatal disease known as malaria because it carries a pathogen known as *Plasmodium spp*. There are six species (maybe more!) of *Plasmodium* that can cause malaria in humans: *P. falciparum*, *P. vivax*, *P. ovale*, *P. malariae*, *P. knowlesi*, *and P. cynomolgi*. Like all mosquitoes, the *Anopheles* mosquito also has four life stages: egg, larva, pupa, and adult. Three of the stages are aquatic and last between 7 and 14 days, depending on the ambient temperature and species. The parasitic stage is the adult stage,

as female mosquitoes need blood meals for egg production, which is the link between humans (along with apes and monkeys) and the mosquito hosts in the parasitic life cycle. Just like the *Aedes* mosquito, *Anopheles* tend to bite during the day (CDC 2020). Successful development of *Plasmodium spp.* in the mosquito depends on ambient temperature, humidity (promotes growth), and the survival of *Anopheles* for the parasites to complete their sporogonic cycle in its definitive host (CDC 2020).

The last mosquito that acts as a parasitic vector we will discuss is the *Culex spp*. mosquito. It takes 7–10 days for the eggs to develop into an adult, where, again, the female mosquito can become a parasitic vector as it eats a blood meal for reproduction. This mosquito, which primarily bites at night, causes the transmission of pathogens such as the West Nile virus, filariasis, and various kinds of encephalitis (CDC 2022). *Culex* mosquitoes are not able to fly long distances but have been known to fly about two miles. They prefer to live outdoors near birds and homes, as they like to feed off birds and humans when other animals are not nearby (CDC 2020). Filariasis is transmitted from person to person when a female *Culex* mosquito feeds off an infected person, while encephalitis (which is primarily in Asia) is transmitted when a female mosquito feeds off an infected pig or wading bird. Lastly, the West Nile virus is transmitted when a mosquito feeds on an infected bird and bites a human or another animal (CDC 2020).

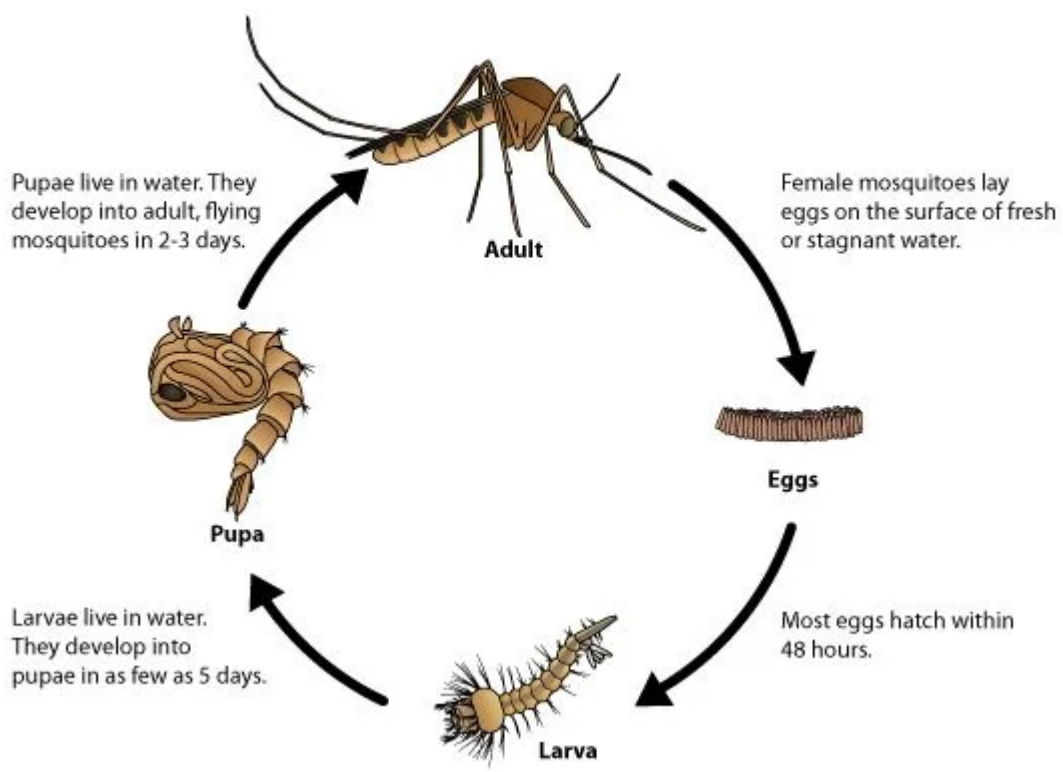

Fig. 6. Culex Life Cycle as described by the **CDC**.

New and Emerging Mosquito-Borne Diseases

A broader question than before: If everything was created good in the beginning, then why do new diseases keep emerging? Also, why do prominent diseases keep reemerging with new strains? These are some of the questions that **Christian [http://answersingenesis.org/christian/]** biologists (and often even lay Christians) are asked. And thankfully, the answers are straightforward. These changes can be caused by mutations, gene loss, overabundance, and zoonotic displacement (Gillen and Conrad 2021).

Overabundance provides a surge of resources that creates a habitat for more pathogens. For example, when hurricanes occur along the gulf coast, the rushing water through yards and streets picks up a variety of pathogens and carries them to new places. This sudden abundance and ubiquity of pathogens makes the public more susceptible than before. Lastly, zoonotic diseases

are one of the main causes of new diseases. Zoonotic diseases are caused when a pathogen that typically inhabits wildlife or domestic animals is accidentally passed on to humans. Examples of zoonotic diseases include Lyme disease, COVID-19, West Nile, and malaria.

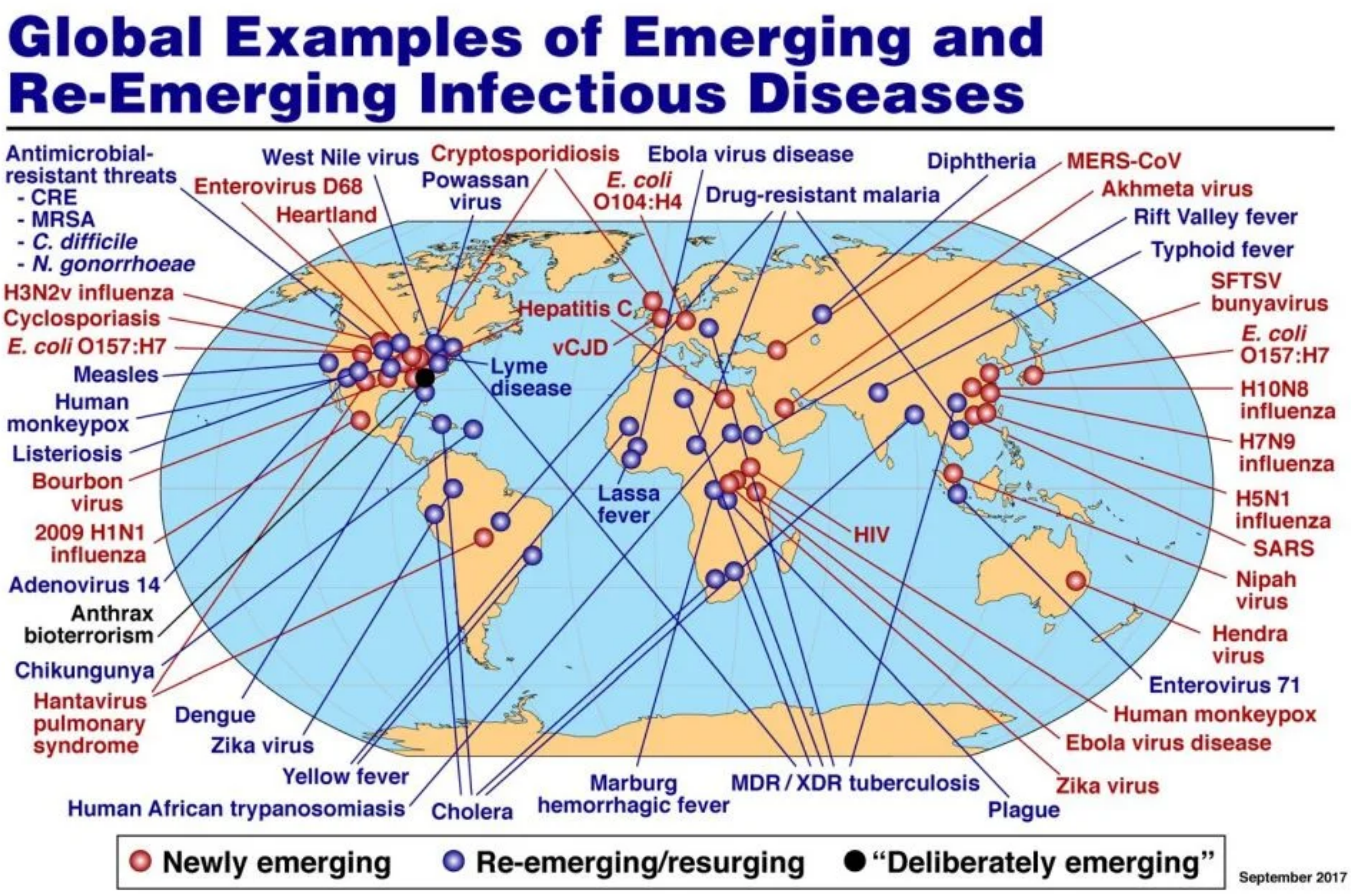

Fig. 7. Map of recent emerging diseases around the world. Image by Lilily via **Wikimedia Commons**.

A current prominent disease in the United States and other countries is known as West Nile virus. This virus has been known to infect both people as well as those of the feline, canine, and equine species. According to the CDC, West Nile virus (WNV) is known as the leading mosquito-borne disease in the continental United States, infecting 2695 individuals in the year of 2021 (as of January 22, 2022). Sixty-nine percent (1855 individuals) of these infections in 2021 showed neuroinvasive symptoms, including meningitis or encephalitis (CDC 2021). The other thirty-one percent experienced symptoms that were classified as non-neuroinvasive diseases. Human West Nile infections have been reported in almost all states except New Hampshire and West Virginia

(CDC 2021). All 50 states have, however, reported West Nile infections in pets or horses. Figure 8 shows the prevalence of WNV infections in the United States.

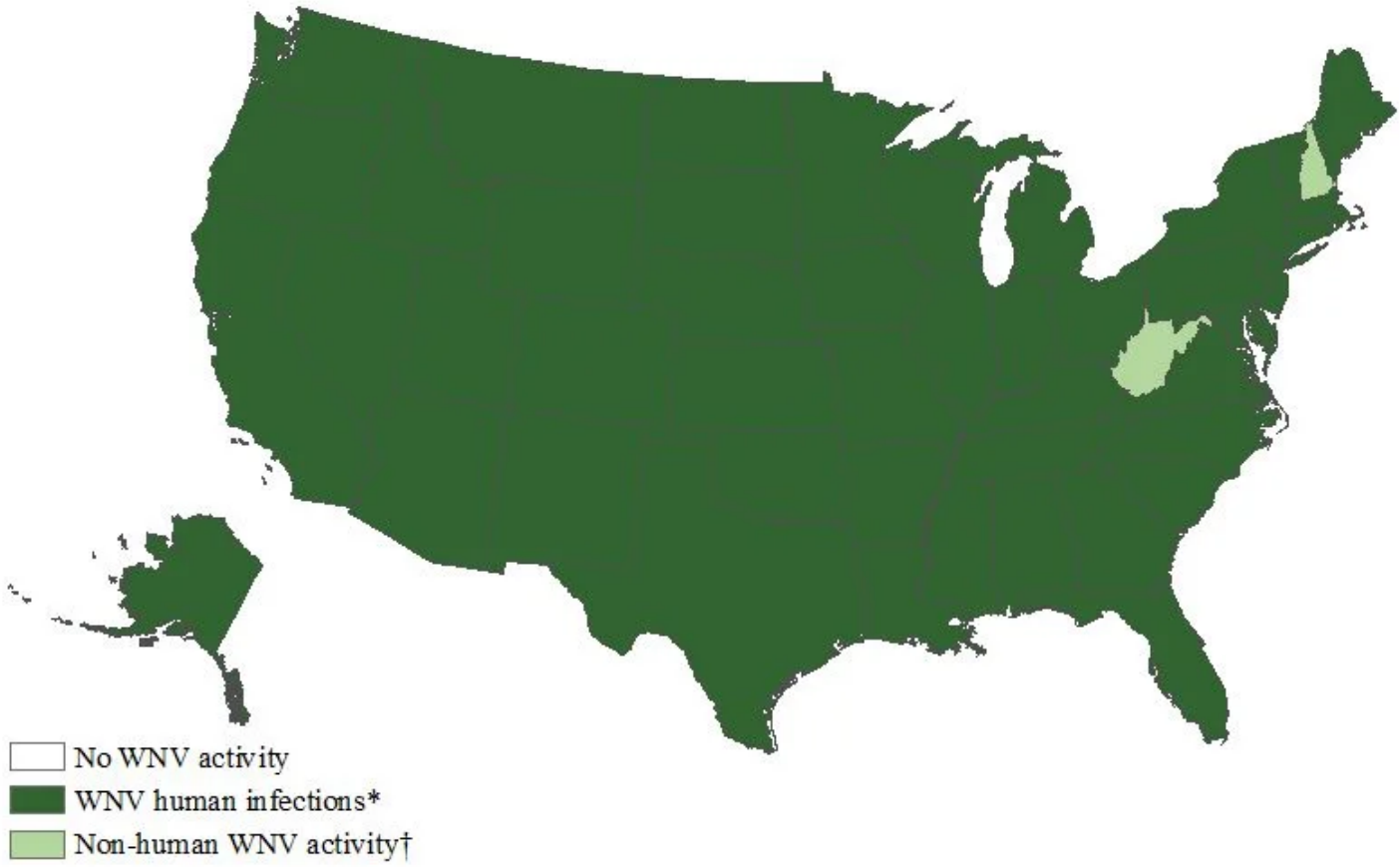

Fig. 8: Prevalence map of human and non-human WNV infections according to the **CDC**.

The transmission of WNV is specifically to people and other mammals through the bite of a mosquito. According to Bosco-Lauth and Bowen in *West Nile Virus: Veterinary Health and Vaccine Development,* dogs, cats, and various livestock, including chickens, can all become infected by WNV but only occasionally develop clinical disease and are typically considered dead-end hosts for the virus. The CDC further confirms these findings and states that "Infected mosquitoes spread West Nile Virus to people and other animals by biting them" (CDC 2021). Few people have been infected through other transmission routes, including laboratory exposure, blood transfusion, or organ transplants (CDC 2021). Some cases of WNV transmission have occurred from a mother to a baby in the womb, during delivery, and through breastfeeding but are exceedingly rare (CDC 2021).

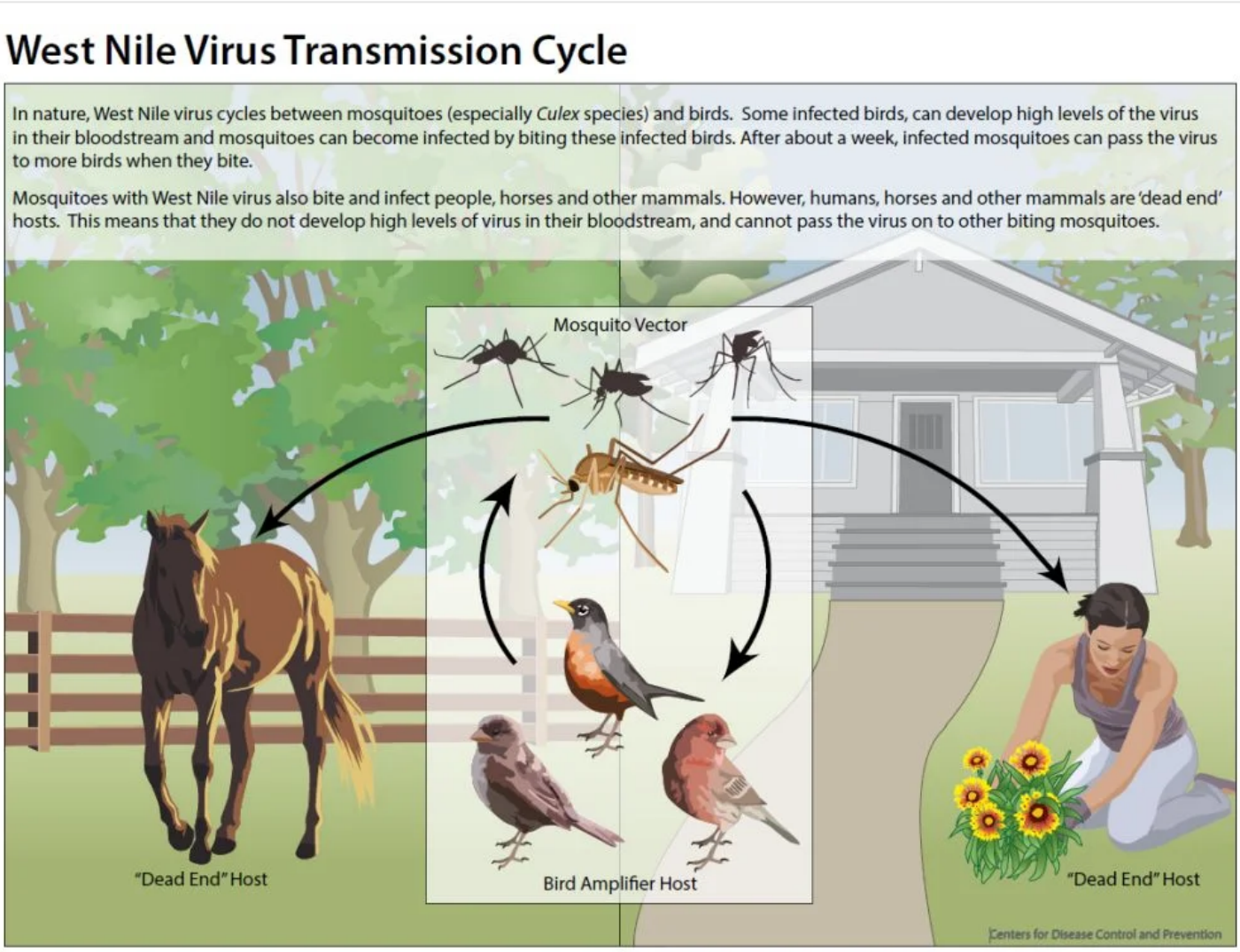

Fig. 9. The transmission cycle of West Nile Virus according to the **CDC**.

The route of WNV transmission is as follows: the mosquito becomes infected by sucking blood from an infected bird, and then the mosquito bites another animal (usually a dead-end host). The dead-end host will then typically show clinical disease symptoms. However, this dead-end host will not pass on West Nile disease via contact with another individual. Figure 9 represents the West Nile transmission cycle, starting with the infected bird to the mosquito and onto a dead-end host (the horse). Other dead-end hosts include humans, dogs, cats, and some other mammals.

Fig. 10. Image of a male *C. pipiens*. Image by Kíváncsi via **Wikimedia Commons**.

There are many species of mosquitoes that have been identified to carry and infect others with West Nile virus. The most common are from the *Aedes*, *Anopheles*, and *Culex* species. Certain *Culex* sub-species have been found to be the predominant vector of WNV in the United States (Molei 2006). These species include *Culex pipiens*, *Culex tarsalis*, and *Culex quinquefasciatus*, all feeding in the early evening to morning and found in specific locations in the United States. *C. pipiens* is commonly found in the Eastern US and is known as the northern house mosquito. It is of medium size and has a brown-to-gray body with brown wings.

Autogenous vs. Anautogenous *Culex* variants

Spielman (2001) has a significant amount of research regarding the autogenous and anautogenous *Culex* variants in New York state. *Autogenous* mosquitoes do not take in blood meals to support their overall energy requirement or for egg development; while *anautogenous*

mosquitoes do require a blood meal for both. *Culex* variants have been found to have many variants, both autogenous and anautogenous. It has been found that some *Culex* variants have interbred, which has caused high variability within the species. This variability influences the blood needs of the subspecies as well as the virulence of the parasite load within each organism. Spielman's study showed that roughly one-third of the population was autogenous while another third was anautogenous, and the last portion of the *Culex pipiens* was intermediate. *Culex* has been identified to have an *ecological cline*, which is an area where the intermediates are located. These intermediates are classified as a hybrid of both the autogenous and anautogenous *Culex*. Due to the unlimited possibilities of how many hybrid *Culex* species exist, the prediction of vectorial capacity is complicated and gives rise to many theories regarding the mosquito "danger factor" and its pathogen spillover.[1] Furthermore, the differences between the autogenous and anautogenous species allow for even more genetic and geographic variability as well as increase the transmission of a pathogen, for example, West Nile Virus.

Autogenous species and anautogenous species not only vary genetically but also geographically. As the water temperatures increase in June, most mosquitoes begin to significantly increase their egg production. The anautogenous species increases tremendously in only two weeks, but their production begins to decline in mid-August. However, the autogenous species continues its rapid reproduction into October. It is uncommon for different species to interbreed with each other because they usually occupy different biological niches. However, an outside agent can encourage mixed breeding. The agents that cause the intermediate species in this case are tropical cyclones. In the Eastern US, late summer/early fall is dubbed hurricane season. These changing weather patterns interfere with the ecosystems of both species, thus temporarily combining them into one. As their genes combine, so do their behaviors. The hybrid species seeks both avian and mammalian blood. Because of this, hybrid species increase pathogen susceptibility (particularly for West Nile virus) to humans.

Ecological Clines of *C. pipiens*

In biology, a *cline* is a measurable gradient in a single biological trait, such as mosquitoes biting humans, of a species across its geographical range, like the campus of Harvard University, or Long Island in New York (Spielman 2001). In an ecological cline, where hybrids of two or more species occur, it is sometimes hard to distinguish the species. Autogenous species of *C. pipiens* like to live near enclosed areas close to the ground. Anautogenous species like to live in more open spaces that are frequently higher in elevation (Spielman 2001). Spielman conducted a study in Boston, MA, at the Harvard Medical School campus. He collected larvae samples from different locations on campus and recorded the water temperature. The density of the larvae was also recorded. It was found that when water reaches 15°C, larvae were present in the water sites, but when the water fell below 15°C, breeding decreased. This temperature range is found during the months of June through September. Additionally, it was found that anautogenous species do not reproduce if days are less than 14 hours and 15 minutes in duration. During the summer months, day length increases with latitude. Therefore, northern areas of the US are more susceptible to West Nile outbreaks than the southern US. The northern *C. pipiens* ranges as far south as 33 degrees north. In conclusion, pathogens from *C. pipiens* may increase rapidly in the northern US until about mid-August and affect human hosts thereafter. Not only that, but the intensity of transmission decreases toward the south (Spielman 2006). Though they breed extensively in warmer temperatures, many mosquito eggs can survive the harshest winter conditions. This ability to survive many harsh summer and winter conditions results in higher numbers of mosquito population throughout the US, especially in the more moderate areas including Texas and California, surviving for a longer period.

Ecotypes

C. pipiens has been identified in various parts of the world with a significant preference for temperate areas. Figure 11 represents the locations at which *C. pipiens* and *C. quinquefasciatis* have been identified, with an area that is representative of both species found in the same area. In heavily populated areas of the United States, *C. pipiens* has been found to have developed ecotypes. An *ecotype* is known as a specific environment that one species or subspecies has

adapted to in order to increase the chance of survivability. In northern heavily populated areas, *C. pipiens* have been found to live in aboveground and belowground populations. These populations are typically genetically different and have little interaction with the other. The different ecotypes result in different possibilities for the spread of disease and life of the mosquito.

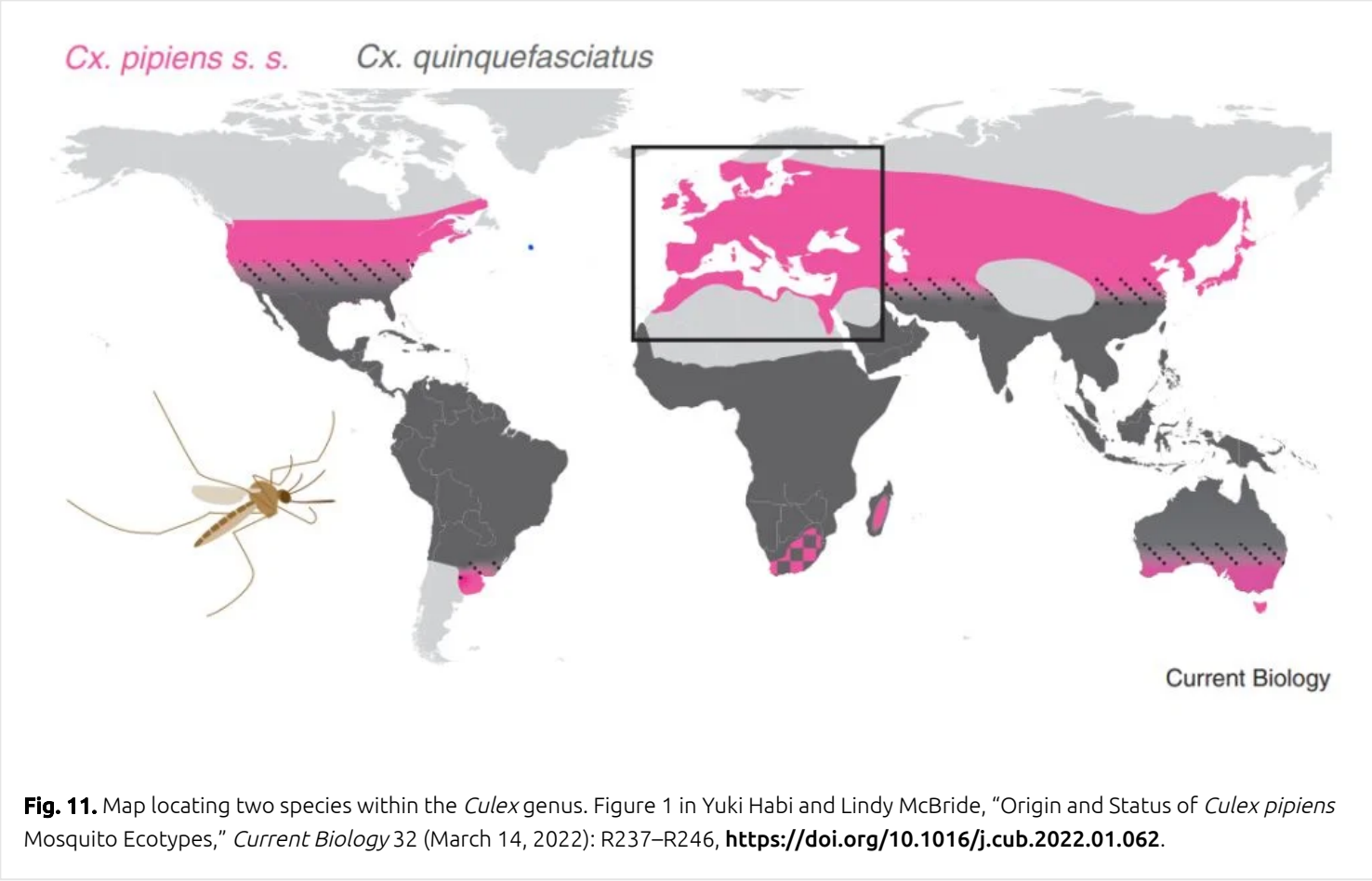

Fig. 11. Map locating two species within the *Culex* genus. Figure 1 in Yuki Habi and Lindy McBride, "Origin and Status of *Culex pipiens* Mosquito Ecotypes," *Current Biology* 32 (March 14, 2022): R237–R246, **https://doi.org/10.1016/j.cub.2022.01.062**.

For the *C. pipiens* of the aboveground ecotype in the north, it would be expected that the mosquito would mate in a warm atmosphere, and it would require a blood meal for the development of the eggs to occur. Furthermore, those in the north would go into a state known as *diapause*, which is when the mosquito becomes stagnant in its development. Those hybrids further south are more successful at producing viable offspring regardless of a blood meal and are far more active year-round due to a preferable climate. Additionally, northern mosquitoes are more likely to take in blood meals from birds, whereas the southern mosquitoes are more likely to take blood meals from a human.

An additional concern with these ecotypes is a lack of genetic variation between aboveground and belowground *C. pipiens*. These ecotypes are typically separated and very rarely interact and breed with one another. This lack of variation could cause significant mutations in the species, which would result in an unlimited number of unknown problems for the mosquito, the diseases it carries, and the individuals that come in contact with *C. pipiens*. Occasionally, contact with the aboveground and belowground individuals has been known to occur; however, it is rare and is usually caused by significant weather changes. The contact with the two species allows for genetic variation within the ecotypes. An updraft in an area with the two ecotypes usually pulls the belowground ecotype upward and enables the two groups of *C. pipiens* to reproductively interact. Ecotypes are a vital part of understanding how *C. pipiens* interacts and the reason why they are prominent in carrying WNV as well as other bacteria and viruses.

Figure 12: Walter Reed and James Carroll. Reed holds up test tube of filterable virus obtained from mosquitoes. First experimental evidence of a virus causing human disease. Image by Alan L. Gillen.

Christian Mosquito Hunter: Walter Reed

Christians have played a key role in the discovery of mosquitoes and pathogens, and one of the most notable was Walter Reed, a US Army physician who was born to a circuit-riding Methodist minister on September 13, 1851, in Belroi, Virginia (Britton 2021). Even at a young age, he was a remarkable individual who was known for his self-control, hunger for knowledge, and honor, all which would carry him far. At the young age of 16, he acquired special dispensation to matriculate as a medical doctor at the University of Virginia (Britton 2021).

It was 35 years later that Walter Reed confirmed that the transmission of yellow fever was through infected mosquitoes. This historical discovery came about because of two experimental shacks built under Reed's supervision and the willingness of Private John R. Kissinger to be bitten by infected mosquitoes. Walter Reed and James Carroll demonstrated that yellow fever is caused by a filterable virus carried by mosquitoes (Fig. 11). This is the first evidence that viruses cause human disease.

The nature of the yellow fever agent was established in 1901, when Reed and Carroll took yellow fever patient filtered blood serum and injected it into three healthy individuals. Two of the volunteers developed yellow fever, causing Reed and Carroll to conclude that a filterable agent, now known as yellow fever virus, was the cause of yellow fever. (Truby 1943).[2]

Thus, modern public health and preventive medicine owe much to the early work of these two godly men and American heroes. At the end of discovery, instead of rejoicing in himself, he gave God the glory and thanked him for using him as a vessel, which is what all individuals should do.

Reed's discovery was extremely important because it eventually led to the elimination of yellow fever from the island of Cuba, as it was learned that the breeding grounds of mosquitoes needed to be controlled (Britton 2021). On November 23, 1902, Walter Reed passed away at the age of 51 years old. At the end of his life, he rejoiced that God used him for good and was filled with happiness that he could participate in helping humanity suffer a little less (Britton 2021).

Conclusion

The mosquito has been assigned a significant role within the environment to ensure the success in the growth of many plants. While the mosquitoes take in nectar, they also collect some pollen and pollinate other flowers in return. This relationship is considered mutualistic, and both parties

benefit. It is vital to understand, however, that only the males use their proboscis to drink nectar and pollinate other plants. After the fall of man, mosquitoes underwent genetic changes that sometimes required the females to take in blood meals for successful reproduction. These females are the primary vectors for many pathogens, including West Nile virus, dengue virus, yellow fever, chikungunya, and Zika virus. Furthermore, many newer diseases passed by the mosquito-borne vectors are classified as zoonotic. These zoonotic diseases are typically passed on accidentally and have had a significant impact on the health of many humans and animals.

In addition to genetic changes and the vast number of climates on earth, mosquitoes have adapted and changed to survive. As these mosquitoes change, they also must compete with other species. An example of this would be the elephant mosquito, which never sucks blood. However, its diet requires eating other average-sized mosquitoes as well as other nuisance bugs for the necessary nutrition. The instinct to survive and compete further drives the mosquitoes to adapt and reproduce more efficiently.

Furthermore, the mosquitoes' well-adapted reproduction method allows them to produce an abundance of offspring. The ability to survive longer and reproduce more has increased the number of mosquitoes substantially. There are about 3,500 species of mosquitoes worldwide. We have an estimated **110 trillion in 2021** across the earth. The numbers will probably increase due to higher temperatures for longer days. The expected wet weather combined with the excessive heat and fewer bats in 2022 will bring more mosquitoes, thus the chance for more deadly diseases. However, despite the large number of mosquitoes in the United States and across the world, they have a more significant purpose than being a buzzing nuisance and spreading disease. These aspects are only the results of the fall of man. God made all things good and with pure intention, even including the mosquito. Even after the fall, mosquitoes are important to the ecological balance of a specific environment and ensure the success of many plants and animals serving as pollinators and food (for birds, frogs, and more!).

The West Nile virus is one of the most prominent diseases in the United States and is the leading disease caused by a mosquito vector, where 48 states have documented human infections, and all 50 states have reported pet (feline, canine, and equestrian species) infections. This virus is most transmitted when a mosquito ingests the blood from an infected bird and then bites a human or another animal. Occasionally, the virus has spread through blood transfusions, organ donations, or from mother to baby. *Culex* mosquitoes enable them to survive in varied climates, which partially explains why there are so many mosquitoes.

Christians have played a key role in identifying many parasitic diseases, with one of the most notable being Walter Reed, who discovered that *Anopheles* mosquitoes were the cause of the transmission of yellow fever in Cuba. Without God, medical discoveries such as this would not be made known, and humanity would have to suffer more than it already does. Although humans will face the burden of disease until Christ returns and restores a perfect world, thankfully, our gracious God has given incredible minds to researchers to find effective treatments and discover preventative measures.

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Footnotes

1. Microbes, pathogens, and parasites can occasionally move from one species to another in what is called a *spillover event*.
2. See also Habi 2022. Also available at **https://www.virology.ws/2017/06/14/the-first-human-virus-discovered/**.