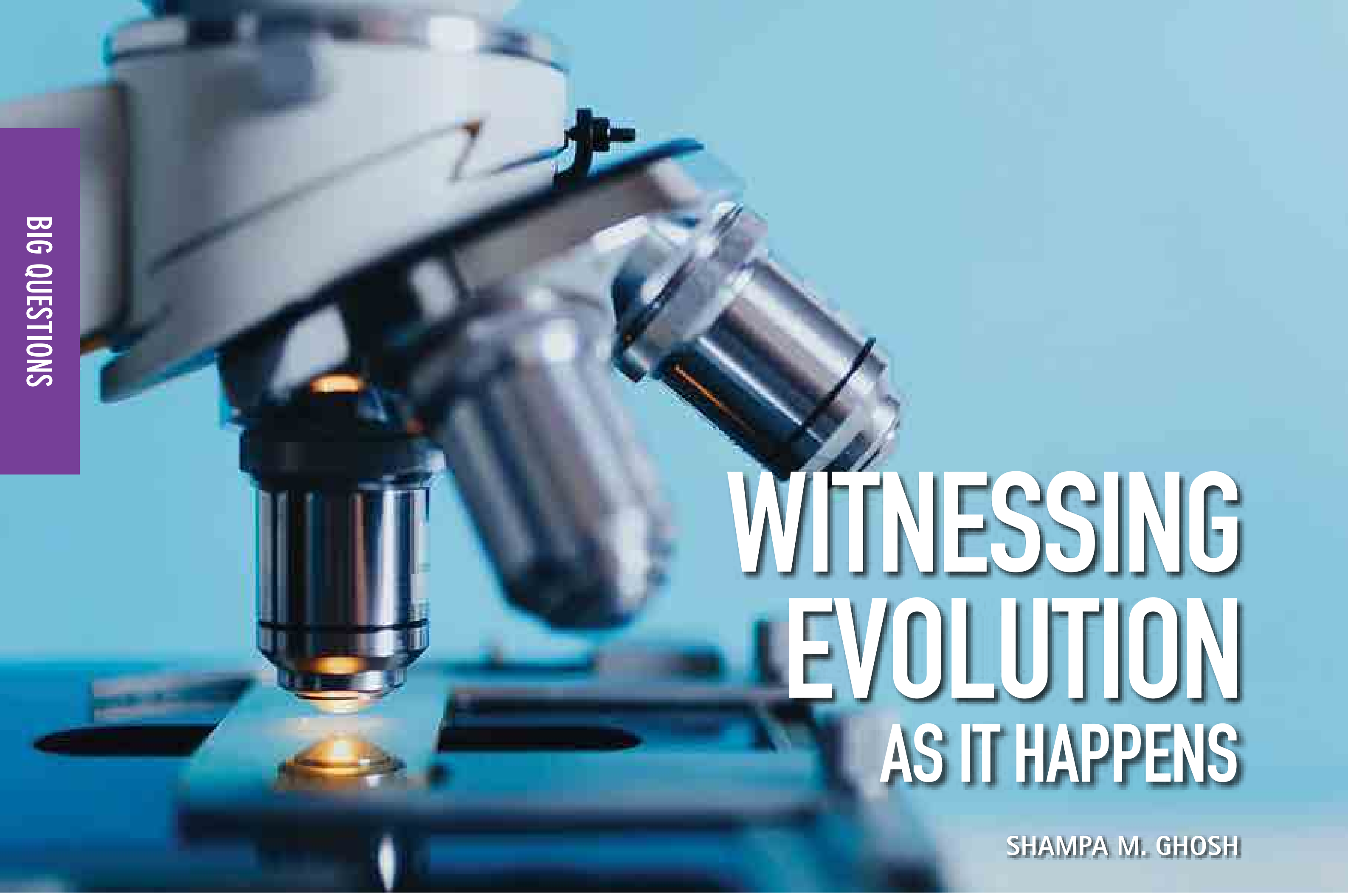

WITNESSING EVOLUTION AS IT HAPPENS

SHAMPA M. GHOSH

Natural selection and evolution evoke images of processes that happened in the distant past. Can we observe evolution in real time? Can we use such observations to understand evolutionary changes in nature?

Evolution is commonly perceived as a process that happened millions of years ago. But, the development of dichlorodiphenyltrichloroethane (DDT) resistance in mosquitoes, and the emergence of the pandemic causing novel coronavirus are just two examples that demonstrate that evolution is an ongoing process. It is occurring, this minute, all around us.

How do we study evolution? Most of us are aware of studies that investigate prehistoric fossils (palaeontology), or compare different species (comparative studies). Few know that this process can also be studied in real time, under the controlled conditions of a laboratory, through an exciting approach called 'experimental evolution'. To do this, lab-grown populations of organisms are subjected to specific selection pressures, and any changes that occur in response to these pressures are tracked over a number of generations. The organisms that are commonly used in this approach are bacteria, nematode worms, fruit flies, etc (see **Fig. 1**). In addition to being easy to grow in lab, these organisms have short generation times, and are genetically tractable. This means that any evolutionary change in these organisms become apparent within a span of a few months or years, and scientists are able to track their underlying genetic causes more easily.

Example I: Evolution of 'postponed ageing'

Why do we age? This question has intrigued us for centuries. Evolutionary biology offers one explanation for this process, called the evolutionary theory of ageing. This theory is based on the premise that the most significant contribution to any populations' reproductive success comes from its young. If an organism dies before it reaches the reproductive age, its genes die with it. Therefore, natural selection

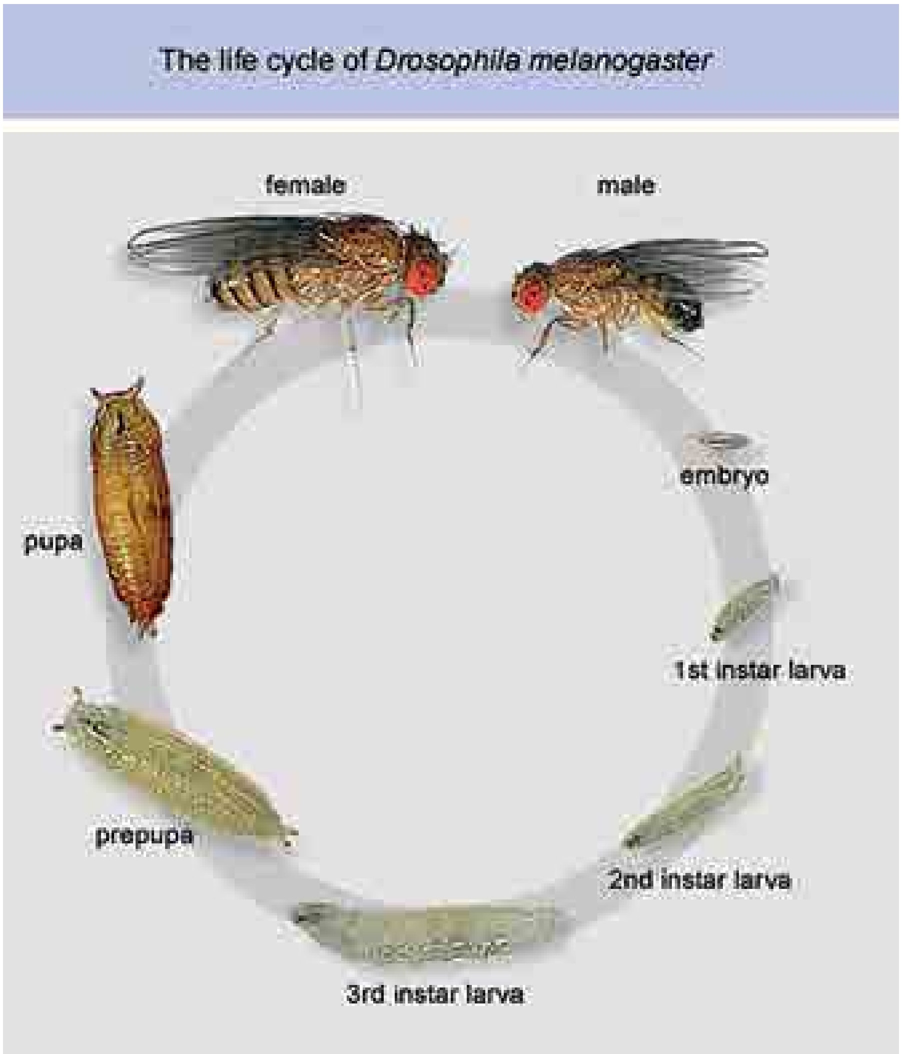

Fig. 1. The fruit fly has a generation time of just 10-12 days at 25 °C. This means that it takes only 10-12 days for a zygote to develop into an adult fly. This process involves several stages of development — embryo, larva (first instar, second instar and third instar), pupa, and adult.

favours genes or traits that help ensure that the young survive long enough to reproduce, and are able to produce healthy offspring. Once an organism survives long enough to mature and reproduce, the selection pressure on it reduces. Even if it dies after that, its genes have been transmitted to the next generation. Hence the selection pressure to keep organisms fit weakens with age, and hazardous late-acting genes continue to exist in the species. This causes a number of changes in the organism, like the accumulation of oxidative damages within cells or the weakening of body parts. As a result, the organism's health shows a gradual decline, leading to ageing or senescence.

Can we delay ageing, and increase lifespan? Professor Michael Rose from the University of California (UC), Irvine, USA, attempted to answer this question in the fruit fly *Drosophila melanogaster* (see **Fig. 2**). The average lifespan of the adult fruit fly is about 35-40 days. The female lays eggs throughout its lifespan, but the number of eggs it produces reduces drastically as the fly ages. Rose decided to delay the age at which these flies reproduce for the first time, and repeat this in every generation. He predicted that flies in this population would show the evolution of two traits — delayed ageing and longer lifespans. Why? Because under such conditions, natural selection would favour flies that lived longer, stayed fitter, and produced more eggs than other flies at that age.

To test his prediction, Rose and his colleagues started with five replicate populations of fruit flies. These lines were derived from a wild caught population to ensure that they showed more variation than many of the inbred lines of flies commonly used in the lab. They divided these populations into two groups — B (for 'Base') and O (for 'Old'). Eggs from flies in the B populations were collected at their normal reproductive age. In contrast, eggs laid by only the oldest living flies in the O populations were used to initiate the next generation, while those laid prior to that age were discarded. This selection regime was repeated for many generations, with egg collection pushed to a later age in each subsequent generation of the O populations.

Flies in the O populations responded to this selection for late-age reproduction remarkably fast. As predicted by Rose, they not only evolved the ability to produce more eggs at an advanced age, their lifespan also continued to increase through the course of the study. After a decade (~ 75 generations) of selection, the average lifespan of flies in the O populations was more than double that of the flies in the B populations. According to the latest report, O populations have evolved to live four times longer than a normal fruit fly!

Fig. 2. An adult fruit fly (*Drosophila melanogaster*) feeding off a banana.

Rose named these long-lived *Drosophila* populations 'Methuselah flies' after Methuselah, the longest living man according to the Hebrew Bible. But this was not all. The O flies also showed greater metabolic storage, and increased resistance to starvation, desiccation, and oxidative stresses. In effect, these flies remained young much beyond the normal age of *Drosophila*. These results supported the evolutionary theory of ageing by demonstrating that ageing could be postponed if natural selection remained effective in older animals.

Example II: Evolution of faster development

Can we shorten the duration of development of an organism? One answer to this question comes from observations of insects such as *Drosophila* in the wild. These insects develop within rotting fruit. As the larvae grow, they compete with each other for food. They also excrete their toxic waste within the fruit, making it increasingly inedible. Therefore, if all else remains equal, natural selection is expected to favour flies that can develop into adults more rapidly than others. Four research groups in the 1990s used this argument to successfully rear a population of fruit flies that developed faster than normal. One of these groups was headed by Professor Amitabh Joshi from the Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), Bangalore, India.

Joshi's group subjected four replicate populations of *Drosophila* (called JB for Joshi Baseline populations) to the following selection regime — in each generation, only 25% of the fastest developing flies were allowed to reproduce, while the remaining 75% were discarded. In addition, these flies were allowed to breed at a younger age than those in the control population. This imposed a strong selection pressure to develop fast, since the flies that could not do so were not allowed to pass on their genes to the next generation. By the 100th generation, the time taken for egg-to-adult development in these FEJ (or Faster-developing, Early-reproducing, JB derived) fly populations was three-fourths that taken by their ancestors!

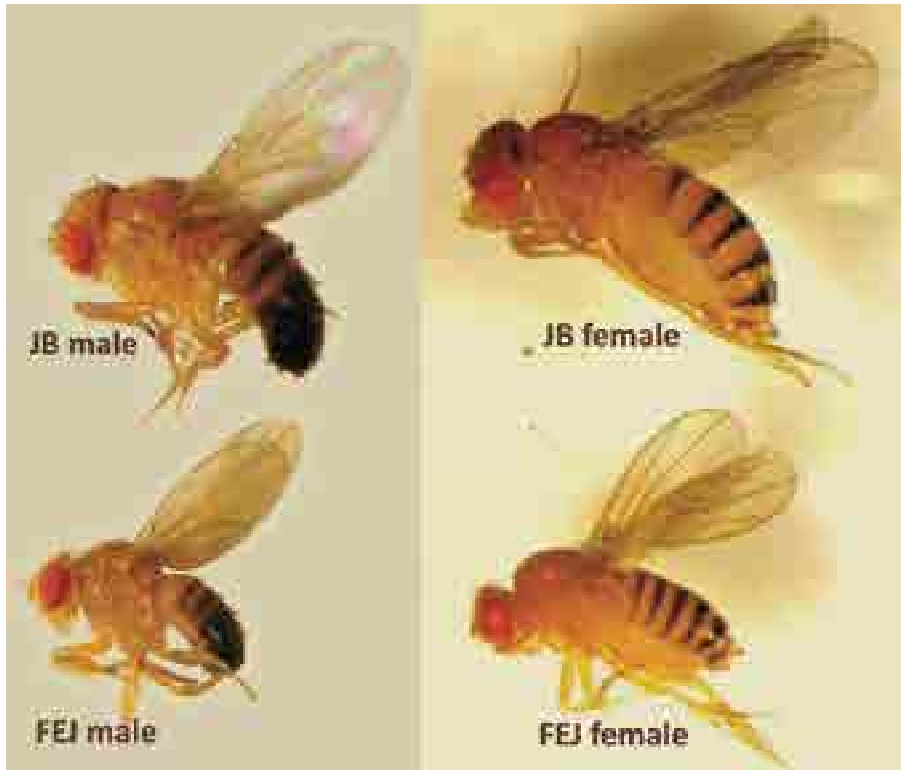

Fig. 3. Flies in the FEJ population are much smaller than those in the JB population.
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But they paid a heavy price for this ability — showing greater larval mortality, lower lipid reserves, reduced stress resistance, and lower reproductive output, among other things. This is because the duration of development is of utmost importance in the life history of *Drosophila*. As a larva, the fruit fly can feed voraciously and grow in size. But, once it gets encased in a pupal case for metamorphosis, the larva loses some of its body mass; and as an adult, the fly's hard exoskeleton prevents any further growth in size. This means that the size and energy needs of an adult fly, for the rest of its lifespan, are largely dependent on the amount of time it invests in larval feeding. This is why faster development in FEJ flies would result in poorer growth and lower energy reserves, leading to reduced energy allocation for various traits, including egg production. This seems to suggest that it may not be possible to maximize or improve one trait, without affecting other traits. It also seems likely that the average duration of development that we see in nature is one that balances the various life history traits of an organism. Hence, contrary to what was expected, natural selection may not favour flies that develop so fast that it affects other traits.

Interestingly, FEJs also evolved smaller body sizes — by the 70th generation, these flies were only half the size of JBs (see **Fig. 3**). A series of crosses revealed that flies from the FEJ and JB populations were less capable of successful interbreeding. Since reproductive isolation between two groups of organisms defines them as two different species, the FEJ study also provides a rare example of progress towards speciation (or, the formation of a new species) in the laboratory.

Parting thoughts

Experimental evolution is an extremely powerful approach to study evolution. It offers us the opportunity to observe this process in real time, design replicable laboratory experiments to investigate specific evolutionary hypotheses, and track the underlying genetics of evolutionary changes. In an era of massive environmental upheavals like deforestation, habitat loss, and global warming, this approach can be a great tool to understand and predict evolutionary changes in nature.

Key takeaways

- Experimental evolution offers an exciting opportunity to observe evolution in real time within the laboratory setup.
- In this approach, evolution is studied by subjecting a population of organisms to specific selection pressures in the laboratory for many generations.
- The most common organisms used in this approach include bacteria, nematode worms, and fruit flies, although other small organisms can be used too.
- This approach allows us to study evolved responses, including genetic changes, in great detail.
- This approach has led to the evolution of fruit flies with longer life spans and faster development in the laboratory.

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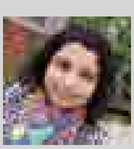

Shampa M. Ghosh is an Assistant Professor at the Kalinga Institute of Industrial Technology (KIIT), Bhubaneswar. Her lab works on experimental evolution and evolutionary developmental biology using *Drosophila.* She can be reached at shampa.ghosh@kiitbiotech.ac.in.