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Laboratory Life

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Olivia Judson on the influence of science and biology on modern life.

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Here's a problem: evolution never stops.

Imagine you're a wild fruit fly, of the species Drosophila melanogaster. You're happily feasting on some yeast that's growing on rotting fruit when, *whoomf*, you get sucked into a bottle and taken to a laboratory. From now on, this is your home.

Life in a bottle — or cage — is different from life in the wild. In nature, for example, fruit flies reproduce throughout their adult lives. Often, in the laboratory, they do not: flies grown in bottles may only be allowed to reproduce for the first five or six days after emerging from the pupa. (Wild flies can live for more than 80 days.) In nature, flies choose their mates. Often, in the laboratory, they do not: they are often assigned to one, and that one may be a close relative. On top of that, the food is different; infectious diseases are rare; predators are absent.

In short, the pressures of daily life have been transformed — and traits that were an advantage Out There may no longer be so Inside. Similarly, traits that would have killed you in the wild may help you get along inside a bottle.

If, for example, older flies are never allowed to reproduce, the ability to lay eggs later in life becomes irrelevant, so there's nothing to prevent the appearance of mutations that interfere with that ability. Indeed, if those mutations increase early fertility, they may even be favored: the most fecund young flies are likely to leave the most descendants.

Thus, the switch from the wild to the laboratory immediately alters the evolutionary trajectory of a population — and sure enough, within a few generations, laboratory-bred life-forms become noticeably different from their wild cousins.

Exactly what happens depends on how the organisms are kept — different rearing methods create different evolutionary forces. But in general, laboratory Drosophila melanogaster evolve shorter lifespans than wild flies; they become less able to cope with stresses like starvation or desiccation; and their pattern of fertility changes. As you'd expect, females reared in bottles evolve to be hugely fecund as young flies but much less

so when they are older.

Also as you'd expect, laboratory evolution is not unique to Drosophila melanogaster. In the wasp Nasonia vitripennis, females descended from a long line of laboratory wasps evolve to be more prone to promiscuous sexual behavior than wild wasps. In the Mediterranean fruit fly, Ceratitis capitata, laboratory-reared females evolve to be less fussy about who they mate with, and male sexiness changes. Wild female medflies don't find laboratory-reared males as attractive as they find wild males. Mexican fruit flies, Anastrepha ludens, have the same problem: laboratory males have evolved in such a way that they are less popular with wild females.

Mice show a host of changes, too. Compared to their wild relations, laboratory mice are typically bigger, more docile, reach sexual maturity earlier and die younger. Some of these changes can appear quickly: one study found that the ability to reproduce later in life declined within 10 generations of the mice being bred in the laboratory.

Intriguingly, laboratory mice also have longer telomeres than wild mice. (Telomeres are the segments of DNA at the ends of chromosomes; they are thought to play a role in aging and cancer.) Since no one is deliberately breeding mice for extra-long telomeres, this must arise as some consequence of laboratory life. But what?

That's not clear. One possibility is that it's due to inbreeding — for lab mice are often highly inbred. Consistent with this, one study of white-footed mice, Peromyscus leucopus, found that, when animals were forced to inbreed, telomeres lengthened substantially in fewer than 30 generations — although why this should be so is entirely mysterious.

All of which is fascinating. But does it matter?

That depends. For some scientific problems, the fact that laboratory life-forms evolve substantial differences from their wild relatives is irrelevant. For others, however, it matters a lot.

Let me give you two examples. Adaptation to the laboratory — or to captivity more generally — can make it much more difficult for organisms to thrive if they are later released to the wild. This has important implications for the conservation of endangered animals and for the control of pests. Captive breeding programs have been important tools for re-establishing wild populations of species such as the California condor; but not all programs are successful. Genetic changes in captivity may be one reason. Similarly, many pest control programs depend on the "sterile male technique," whereby males are bred in the laboratory, sterilized, then released into nature to mate with wild females. For this to work, the wild females must find the laboratory males attractive. Changes in mating behavior like the ones I mentioned earlier can, therefore, quickly reduce the

effectiveness of the approach.

A second area where laboratory evolution can be a serious problem is in the study of subjects like the evolution of aging, and the diseases associated with it. For example, the study of laboratory populations may give a misleading impression of how easy it is to extend lifespans: since laboratory organisms tend to have unnaturally short lifespans, discovering ways to make them live longer may not be especially informative. We may simply be reversing the unnatural shortening that we created in the first place, a view supported by the fact that selection to increase lifespan in laboratory populations often simply restores it to levels seen in the wild.

Such realizations have led an increasing number of scientists to argue that long-established laboratory populations are "suspect starting material" for understanding aging, and that comparisons with wild populations "support the pessimistic interpretation that laboratory-adapted stocks of rodents may be particularly inappropriate for the analysis of the genetic and physiological factors that regulate aging in mammals."

For some subjects, it's better to go wild.

Notes:

For an interesting overview of evolution in the laboratory, see Artamonova, V. S. and Makhrov, A. A. 2006. "Unintentional genetic processes in artificially maintained populations: proving the leading role of selection in evolution." Russian Journal of Genetics 42: 234-246.

A large number of studies have found evidence of evolution to laboratory conditions. For Drosophila melanogaster, I drew, in part, on Sgrò, C. M. and Partridge, L. 2000. "Evolutionary responses of the life history of wild-caught Drosophila melanogaster to two standard methods of laboratory culture." American Naturalist 156: 341-353. This paper shows how differences in laboratory rearing methods can affect evolutionary trajectories, and also shows how truncating the reproductive life of adult flies rapidly leads to flies evolving to reproduce more earlier; compared to wild flies, laboratory flies had shorter lives. For laboratory populations being "suspect starting material" for aging studies, see page 351 of this paper.

For the lifespan of wild flies compared to laboratory flies, see Linnen, C., Tatar, M. and Promislow, D. 2001. "Cultural artifacts: a comparison of senescence in natural, laboratory-adapted and artificially selected lines of Drosophila melanogaster." Evolutionary Ecology Research 3: 877-888. These authors show that wild flies live longer than standard laboratory flies, and that lines of flies that have been bred specifically to have long lifespans do not live longer than wild flies.

For laboratory rearing leading to loss of resistance to desiccation and starvation, see Hoffmann, A. A. et al. 2001. "Rapid loss of stress resistance in Drosophila melanogaster under adaptation to laboratory culture." Evolution 55: 436-438. For promiscuous laboratory wasps, see Burton-Chellew, M. N. et al. 2007. "Laboratory evolution of polyandry in the parasitoid wasp Nasonia vitripennis." Animal Behaviour 74: 1147-1154.

For evolution in the mating behavior of laboratory populations of medflies, see Rodriguero, M. S. et al. 2002. "Sexual selection on multivariate phenotype in wild and mass-reared Ceratitis capitata (Diptera: Tephritidae)." Heredity 89: 480-487. For the same phenomenon in Mexican fruit flies, see Rull, J., Brunel, O. and Mendez, M. E. 2005. "Mass rearing history negatively affects mating success of male Anastrepha ludens (Diptera: Tephritidae) reared for sterile insect technique programs." Journal of Economic Entomology 98: 1510-1516. These papers also discuss the problems that laboratory evolution pose for pest control. An additional analysis of this is provided by Hendrichs, J. et al. 2002. "Medfly areawide sterile insect technique programmes for prevention, suppression, or eradication: the importance of mating behavior studies." Florida Entomologist 85: 1-13.

For an overview of evolutionary changes in laboratory mice, see Miller, R. A. et al. 2002. "Longer life spans and delayed maturation in wild-derived mice." Experimental Biology and Medicine 227: 500-508. This paper shows that wild-caught mice live much longer than most laboratory mice, and reach sexual maturity later. These authors are also responsible for the "pessimistic interpretation" quotation; see page 507.

For the study showing that the ability to reproduce later in life can decline within 10 generations of laboratory residence, see Flurkey, K. et al. 2007. "PohnB6F1: a cross of wild and domestic mice that is a new model of extended female reproductive life span." Journal of Gerontology, Biological Sciences 62A: 1187-1198.

For laboratory mice having weirdly long telomeres, see Hemann, M. T. and Greider, C. W. 2000. "Wild-derived inbred mouse strains have short telomeres." Nucleic Acids Research 28: 4474-4478. For inbreeding producing long telomeres in white-footed mice, see Manning, E. L. et al. 2002. "Influences of inbreeding and genetics on telomere length in mice." Mammalian Genome 13: 234-238.

For the possibility that evolution in captivity may pose a potential problem for captive breeding programs, see Woodworth, L. M. et al. 2002. "Rapid genetic deterioration in captive populations: causes and consequences." Conservation Genetics 3: 277-288; and Williams, S. E. and Hoffman, E. A. 2009. "Minimizing genetic adaptation in captive breeding programs: a review." Biological Conservation 142: 2388-2400.

The problem of laboratory mice in aging research has been discussed extensively by

some authors. In addition to the papers I have already mentioned, see Harper, J. M. 2008. "Wild-derived mouse stocks: an underappreciated tool for aging research." Age 30: 135-145; and Miller, R. A. et al. 1999. "Exotic mice as models for aging research: polemic and prospectus." Neurobiology of Aging 20: 217-231.

Many thanks to Bret Weinstein for drawing my attention to the fact of long telomeres in laboratory mice, and for discussions about some of the implications this may have. Many thanks also to Nicholas Judson and Jonathan Swire for insights, comments and suggestions.