

CLASSICS OF SCIENCE: Redi Disproves Spontaneous Generation

Biology

The experiments here described are as easily performed today as they were two and a half centuries ago. Do not fail to appreciate (and to follow) Redi's check of his experiments with the *control flask*, covered so that the suspected flies could not enter.

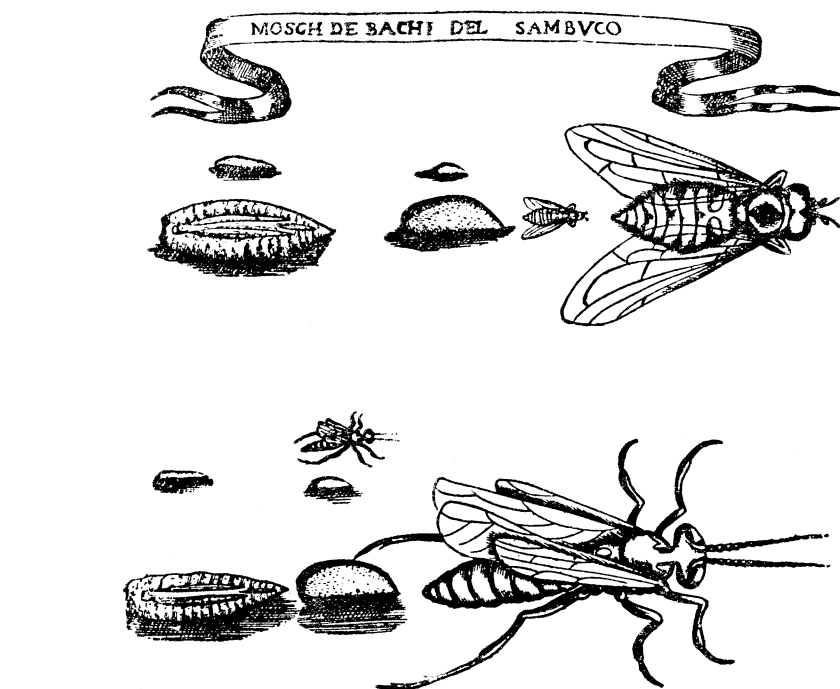
EXPERIMENTS ON THE GENERATION OF INSECTS, by Francesco Redi. Translated from the Italian Edition of 1688 by Mab Bigelow, Chicago, 1909. Original: "Esperienze Intorno alla Generazione degl' Insetti", Firenze, 1668.

Origin of Worms

Although content to be corrected by any one wiser than myself, if I should make erroneous statements, I shall express my belief that the Earth, after having brought forth the first plants and animals at the beginning by order of the Supreme and Omnipotent Creator, has never since produced any kinds of plants or animals, either perfect or imperfect; and everything which we know in past or present times that she has produced, came solely from the true seeds of the plants and animals themselves, which thus, through means of their own, preserve their species. And, although it be a matter of daily observation that infinite numbers of worms are produced in dead bodies and decayed plants, I feel, I say, inclined to believe that these worms are all generated by insemination and that the putrefied matter in which they are found has no other office than that of serving as a place, or suitable nest, where animals deposit their eggs at the breeding season, and in which they also find nourishment; otherwise I assert that nothing is ever generated therein. And, in order, Signor Carlo, to demonstrate to you the truth of what I say, I will describe to you some of those insects, which, being most common, are best known to us.

It being thus, as I have said, the dictum of ancients and moderns, and the popular belief, that the putrescence of a dead body, or the filth of any sort of decayed matter engenders worms; and being desirous of tracing the truth in the case, I made the following experiment:

At the beginning of June I ordered to be killed three snakes, the kind called eels of Æsculapius. As soon as they were dead, I placed them in an open box to decay. Not long afterwards I saw that they were covered with worms of a conical shape and apparently without legs. These worms were intent on devour-



WORMS AND FLIES FROM EGGS FOUND ON ELDER LEAVES. Redi says of them, "Because my brain gives me little help in describing exactly these small animals I send them to you drawn, and in their own natural size, and enlarged also by an ordinary microscope of those of only one glass."

ing the meat, increasing meanwhile in size, and from day to day I observed that they likewise increased in number; but, although of the same shape, they differed in size, having been born on different days. But all, little and big, after having consumed the meat, leaving only the bones intact, escaped from a small aperture in the closed box, and I was unable to discover their hiding place. Being curious, therefore, to know their fate, I again prepared three of the same snakes, which in three days were covered with small worms. These increased daily in number and size, remaining alike in form, though not in color. Of these, the largest were white outside, and the smallest ones, pink. When the meat was all consumed, the worms eagerly sought an exit, but I had closed every aperture. On the nineteenth day of the same month some of the worms ceased all movements, as if they were asleep, and appeared to shrink and gradually to assume a shape like an egg. On the twentieth day all the worms had assumed the egg shape, and had taken on a golden white color, turning to red, which in some darkened, becoming almost black. At this point the red, as well

as the black ones, changed from soft to hard, resembling somewhat those chrysalides formed by caterpillars, silkworms, and similar insects. My curiosity being thus aroused, I noticed that there was some difference in shape between the red and the black eggs [pupæ],¹ though it was clear that all were formed alike of many rings joined together; nevertheless, these rings were more sharply outlined, and more apparent in the black than in the red, which last were almost smooth and without a slight depression at one end, like that in a lemon picked from its stalk, which further distinguished the black egg-like balls. I placed these balls separately in glass vessels, well covered with paper, and at the end of eight days, every shell of the red balls was broken, and from each came forth a fly of gray color, torpid and dull, misshapen as if half finished, with closed wings; but after a few minutes they commenced to unfold and to expand in exact proportion to the tiny body, which also in the meantime had acquired symmetry in all (*Turn to next page*)

¹Throughout this work Redi uses the word "nova" where the context shows that pupa is meant. In this he followed Harvey, who called any embryonic mass an "egg."

Spontaneous Generation—*Continued*

its parts. Then the whole creature, as if made anew, having lost its gray color, took on a most brilliant and vivid green; and the whole body had expanded and grown so that it seemed incredible that it could ever have been contained in the small shell. Though the red eggs [pupæ] brought forth green flies at the end of eight days, the black ones labored fourteen days to produce certain large black flies striped with white, having a hairy abdomen, of the kind that we see daily buzzing about butchers' stalls. These at birth were misshapen and inactive with closed wings, like the green ones mentioned above. Not all the black eggs [pupæ] hatched after fourteen days; on the contrary, a large part of them delayed until the twenty-first day, at which time there came out some curious flies, quite distinct from the other two broods in size and form, and never before described, to my knowledge, by any historian, for they are much smaller than the ordinary house-flies. They have two silvery wings, not longer than the body, which is entirely black. The lower abdomen is shiny, with an occasional hair, as shown by the microscope, and resembles in shape that of the winged ants. The two long horns, or antennæ (a term used by writers of natural history) protrude from the head; the first four legs do not differ from those of the ordinary fly, but the two posterior ones are much larger and longer than would appear to be suitable for such a small body; and they are scaly, like the legs of the locusta marina; they are of the same color, but brighter, so red, in fact, that they would put cinnabar to shame; being all covered with white spots, they resemble fine enamel work. . . .

Are Worms Young Flies?

I continued similar experiments with the raw and cooked flesh of the ox, the deer, the buffalo, the lion, the tiger, the dog, the lamb, the kid, the rabbit; and sometimes with the flesh of ducks, geese, hens, swallows, etc., and finally I experimented with different kinds of fish, such as sword-fish, tun, eel, sole, etc. In every case, one or other of the above-mentioned kinds of flies were hatched, and sometimes all were found in a single animal. Besides

these, there were to be seen many broods of small black flies, some of which were so minute as to be scarcely visible, and almost always I saw that the decaying flesh and the fissures in the boxes where it lay were covered not alone with worms, but with the eggs from which, as I have said, the worms were hatched. These eggs made me think of those deposits dropped by flies on meats, that eventually become worms, a fact noted by the compilers of the dictionary of our Academy, and also well known to hunters and to butchers, who protect their meats in Summer from filth by covering them with white cloths. . . .

The Control Experiment

Having considered these things, I began to believe that all worms found in meat were derived directly from the droppings of flies, and not from the putrefaction of the meat, and I was still more confirmed in this belief by having observed that, before the meat grew wormy, flies had hovered over it, of the same kind as those that later bred in it. Belief would be vain without the confirmation of experiment, hence in the middle of July I put a snake, some fish, some eels of the Arno, and a slice of milk-fed veal in four large, wide-mouthed flasks; having well closed and sealed them, I then filled the same number of flasks in the same way, only leaving these open. It was not long before the meat and the fish, in these second vessels, became wormy and flies were seen entering and leaving at will; but in the closed flasks I did not see a worm, though many days had passed since the dead flesh had been put in them. Outside on the paper cover there was now and then a deposit, or a maggot that eagerly sought some crevice by which to enter and obtain nourishment. . . .

Not content with these experiments, I tried many others at different seasons, using different vessels. In order to leave nothing undone, I even had pieces of meat put under ground, but though remaining buried for weeks, they never bred worms, as was always the case when flies had been allowed to light on the meat. One day a large number of worms, which had bred in some buffalo-meat, were killed by my or-

der; having placed part in a closed dish, and part in an open one, nothing appeared in the first dish, but in the second worms had hatched, which changing as usual into egg-shape balls [pupæ], finally became flies of the common kind. In the same experiment tried with dead flies, I never saw anything breed in the closed vessel.

Hence I might conjecture that Father Kircher, though a man worthy of esteem, was led into erroneous statements in the twelfth book of "The Subterranean World," where he describes the experiment of breeding flies in the dead bodies of the same. "The dead flies," says the good man, "should be besprinkled and soaked with honey-water, and then placed on a copper-plate exposed to the tepid heat of ashes; afterwards very minute worms, only visible through the microscope, will appear, which little by little grow wings on the back and assume the shape of very small flies, that slowly attain perfect size." I believe, however, that the aforesaid honey-water only serves to attract the living flies to breed in the corpses of their comrades and to drop their eggs therein; and I hold that it is of little use to make the experiment in a copper vessel heated by warm ashes, for without these accessories the worms would have bred in the dead bodies. I also frankly confess my inability to understand how those small worms, described by Kircher, could change into small flies without at first, for the space of some days, being converted into egg-like balls [pupæ], nor how those small flies could hatch out so small and then grow larger, as all flies, gnats, mosquitoes and butterflies, as I have observed many times, on escaping from the chrysalis are of the same size that they keep through life. . . .

Francesco Redi was born in Arezzo, Tuscany, in 1626, and died in Pisa, March 1, 1697. Following his father's profession, he graduated in medicine from the University of Pisa, and settled in Florence. He became court physician to the Grand Duke, Ferdinand II, and continued under the patronage of his successor, Cosimo III. Redi, with Carlo Dati, to whom the above book is addressed, and with other scientists of his time, belonged to the Accademia del Cimento, reorganized in 1657 for the investigation of nature according to Galileo's experimental method.