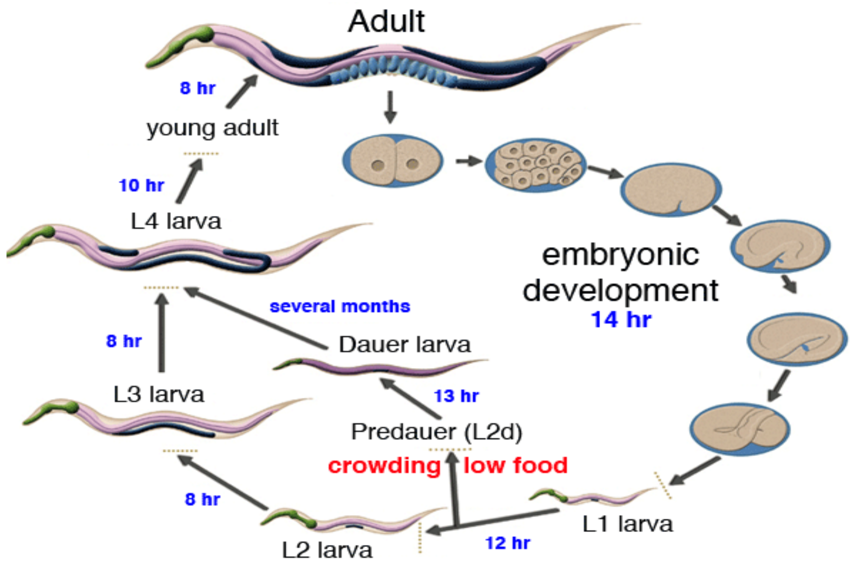
C. elegans Information Sheet

What is *C. elegans*?

Caenorhabditis elegans, or *C. elegans*, is a small (about 1 mm long as an adult), transparent roundworm (nematode) usually found in the soil in temperate climates all around the world. It feeds on microorganisms like bacteria and can be most easily isolated from rotten fruit. In the lab, it is grown by spreading a layer of E. coli onto a plate and letting the animal feed on the bacterial lawn.

Life Cycle



Rapid life cycle: 3 days at 20 degrees Celsius from eggs -> L1-L4 -> adults -> eggs.
Life span: 2-3 weeks.
Offspring: A hermaphrodite can produce about 300-350 offspring under self-fertilization and more if it mates with males.

C. elegans can adopt an alternative life form, called the dauer larval stage, if plates are too crowded or if food is scarce. Dauer larvae are thin and can move but their mouths are plugged and they cannot eat. Interestingly, dauers can remain viable for three months. They appear to be non-aging: dauer larvae can roam around for months and then reenter the L4 stage when they encounter a food source and live about 15 more days! Think about it--those worms can live nearly 10 times their normal lifespan!

At 25ºC a generation time is about 3-4 days, where as it extends to almost a week at 16ºC. Some mutations in *C. elegans* are also temperature sensitive, only showing a phenotype at either 16ºC or 25ºC.

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Growth and Development in Flight

Many experimental results confirm that *C. elegans* appear to have no detectable difficulties with growth and reproduction during spaceflight. Szewczyk's team found that throughout the 12 generations, the Caenorhabditis elegans, or C. elegans worm developed normally from egg to adulthood, moved as it should when fully fed and recovered after a period of induced starvation. “Twelve generations in space is good,” said Paul Sternberg, a nematode geneticist at the California Institute of Technology, who has worked extensively with the C. elegans species, but was not involved in this study.

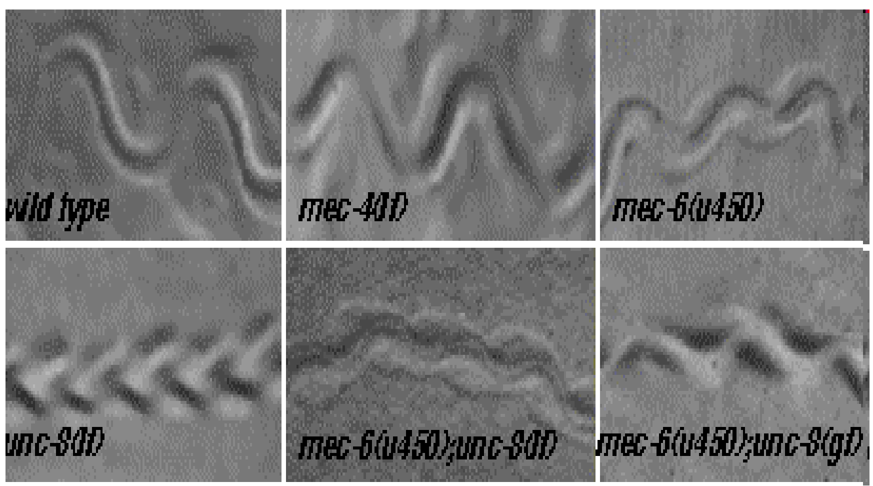
The Effects of Radiation

The worms showed that they could normally repair their radiation damaged cells in spaceflight by using apoptosis, or the programmed cell death which can also be triggered by unusual amounts of damage. Researchers say that this makes them ideal “living dosimeters” to track accumulated radiation damage over time.

The Dead Worms

When the females die the juveniles *consume* bacteria decomposing the female body.

Locomotion



This figure shows one wild type (in upper left corner) and 5 locomotion defect worms. As you can see, the moving pattern of mutants is different from wild type. This is to show how locomotion defect can affect worm’s motion.

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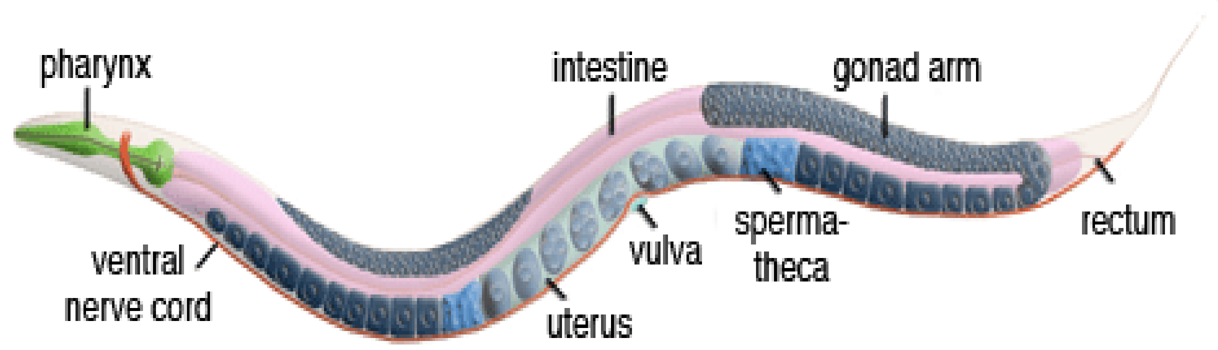
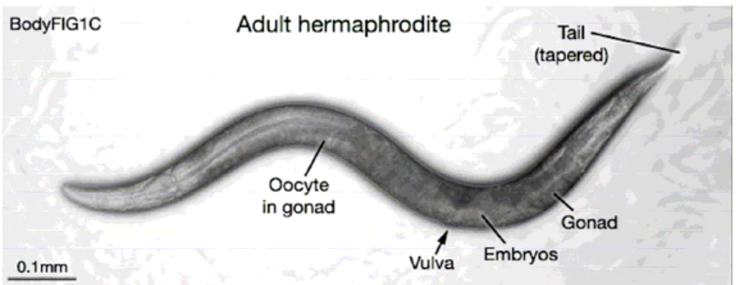
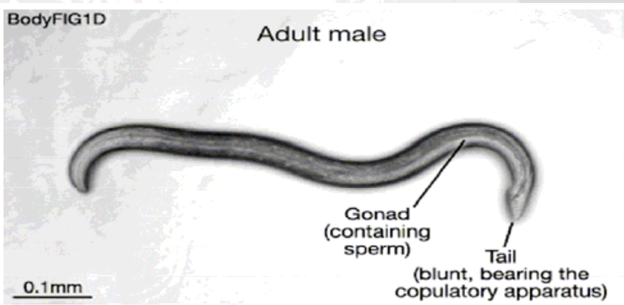
Anatomy



Distinguishing Between the different Sexes

In the diagrams below, note that a hermaphrodite possesses a tapered, pointed tail, whereas a male tail is spade-shaped.





In a population of *C. elegans*, approximately 1 in 500 worms will be male; the rest will be Hermaphrodites.

Why They Are a Model Organism

- Rapid Life Cycle (3 days - 1 week depending on temperature). Life span is 2-3 weeks
- They can be frozen for storage or starved to go into a dormant state and then recover.
- Cheap to maintain
- Small ~ 1mm long
- Genome is sequenced ~ 19,000 genes.
- Simple organism with complex structure
- See through
- Produce 300-350 offspring

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What similarities exist between *C. elegans* and humans?

Although *C. elegans* is a primitive, free living (non-parasitic) organism, it shares many of the same biological characteristics found that are found in you and me. The worm is conceived as a single cell that develops, proceeding through morphogenesis (formation of the structure of an organism or part; differentiation and growth of tissues and organs during development) and growth to the adult. It has a nervous system, muscles to help it move, and a gut. It also is capable of performing very simple behaviors. It produces sperm and eggs, and reproduces, although normally as a hermaphrodite (one having both male and female sexual organs). After reproduction, the worm gradually gets older, slows down, and finally dies.

How can scientists draw comparisons between an organism with a life span of 2 weeks vs. an organism with a life span of 70+ years?

- Scientists utilize a wide variety of model specimens to infer effects on humans. Certain organisms are best suited for the study of certain systems. *C. elegans* are particularly good for studying the muscular system. Some organisms are used to do scientific tests due to their short life span. Short life span allows the scientist to study effects over multiple generations in a relatively short timeframe. In order to get a true sense of what is happening you need to be able to study the effects on multiple individuals. This is typically not possible in studies on humans in space. Lastly, since some experiments might have harmful side effects, it is useful to start by studying effects on different organisms.
- *C. elegans* are well characterized organisms that have a lot of biological functions that are similar to humans thus allowing the scientist to infer what might happen to humans. It is a first step in understanding what effects space might have on the crew. When multiple experiments conducted on different organisms are completed a picture of what should be tested on the crew (using humans) is developed. This strategy is used in modern science and medicine to find new cures for different diseases/ailments that occur to humans here on earth. For example, the treatment of diabetes was developed by conducting experiments on organisms other than humans.

How did studying *C. elegans* advance the US toward its' goal of sending humans to Mars?

C. elegans is an important, well-studied organism used in biomedical research as a model for human development, genetics, aging, and disease. *C. elegans* is also a particularly excellent research organism for space because the worm is small, easy to grow, and easy to keep alive, has a manageable number of genes, and reproduces quickly so many generations can be studied over a short time. By applying carefully what we learn about *C. elegans* in space, we will better understand how biological organisms sense and respond to the spaceflight environment over multiple generations. This is a crucial step towards establishing a permanent manned presence at Mars or space in general. As an example, by using whole genome microarray analysis for ICE, all worm genes can be analyzed for responses to the space environment. These responses may reveal new aspects that could indicate how humans might respond in a similar environment. It is important to recognize that follow-up studies, both on ground and space laboratories, are necessary to confirm how humans will respond.

How do worms go to the bathroom in space?

Like you (only much simpler!), *C. elegans* have a mouth where they take in food, a pharynx that pumps the food into the intestines, a digestive system that enables them to process the food and use the nutrients contained within the food for energy, and an excretory system that enables them to eliminate the waste products from their bodies. So when *C. elegans* need to use the “loo” in the space environment after they eat their food, their bodies utilize the digestive and excretory systems used on Earth to process food and remove energy and waste so they can continue to grow, eat, and live.

How long has NASA been studying *C. elegans*?

The first experiment utilizing *C. elegans* in space was conducted on STS (Space Transportation System)-42, which launched in January 1992. The experiment was designed to study the biological effects of exposure to cosmic rays. This mission contributed to helping scientists understand how to protect space travelers on long missions.

History of Worms in Space

- STS-42 (G. Nelson), Grown on NGM:
  - Males mate
  - Undergo two generations in-flight
  - No gross morphologic defects
  - Increased rate of mutation
- STS-76 (G. Nelson), Suspended in M9:
  - Radiation, not microgravity, key factor in increased rate of mutation
- STS-65 (S. Nagaoka), Grown on ground:
  - Free flow electrophoresis of DNA successful
- STS-95 (E. Moss), Suspended in liquid:
  - Animals died (of hypoxia?)
- STS-107 (C. Conley), Grown on NGM and CeMM:
  - CeMM supported animals in flight
  - Animals survived Columbia breakup