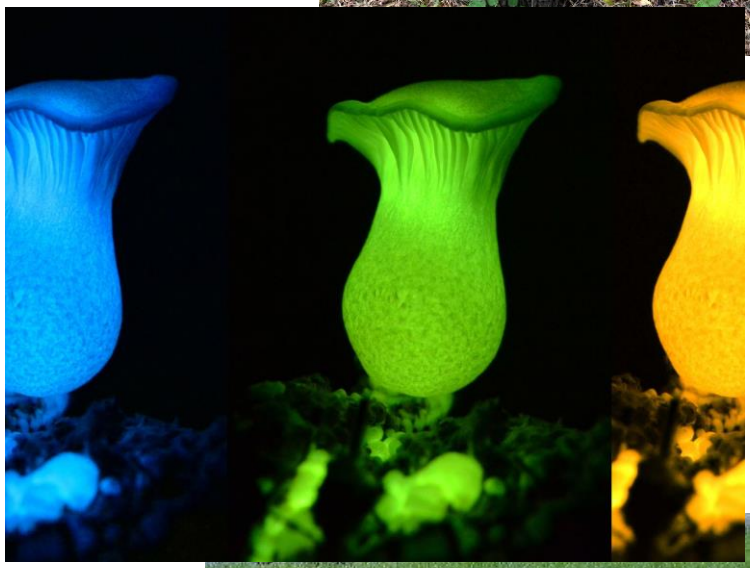
Fungus Nanolab

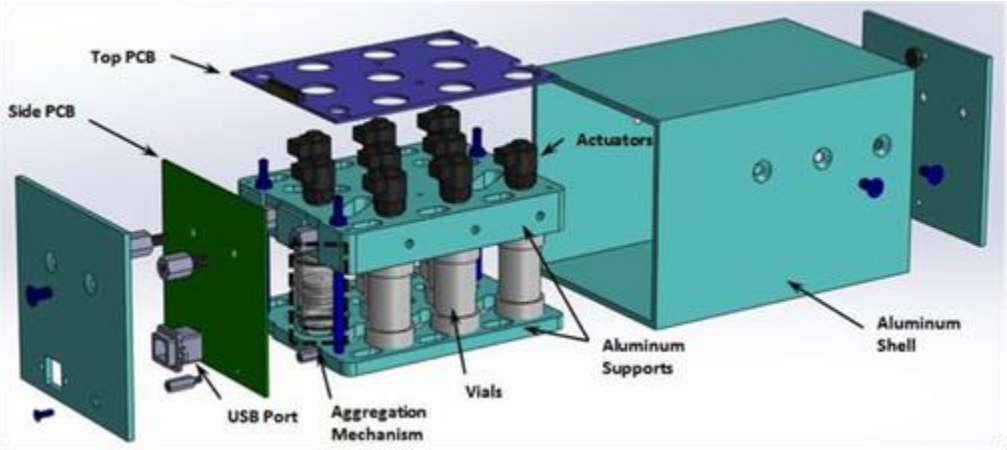
Glenn Johnson

Develop a Nano Lab 10 cm x 10 cm x 20cm for growing different kinds of fungus that will allow the growth of mushrooms but will not allow the release of spores. Decide on the generic placement of sensors and hardware. Coordinate with a software team for developing how equipment needs to start and stop the experiment.



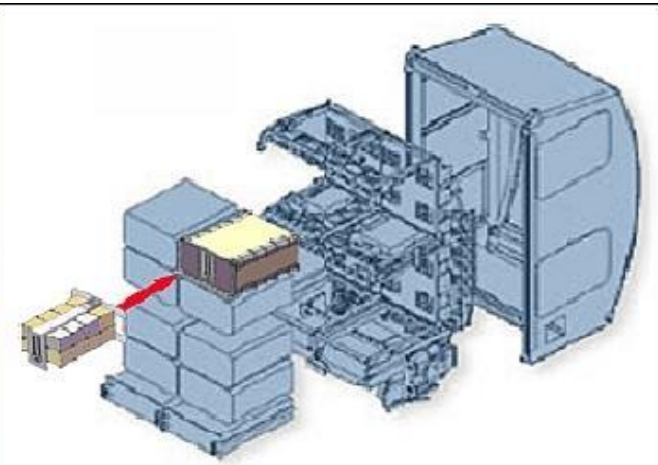
Nanolabs

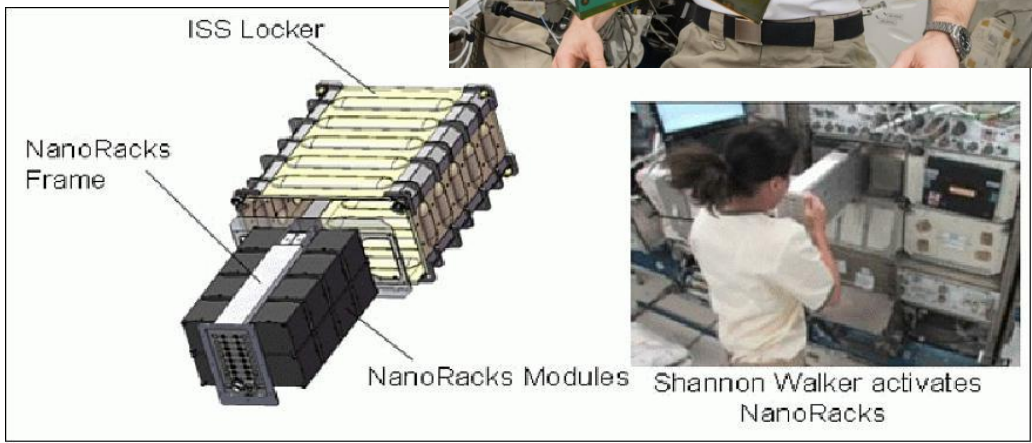
- Nanolabs are small, autonomous, powered experiments that fit inside a specialized ISS Locker that are sent to the International Space Station for testing effects of microgravity on materials, processes, living organisms and many other experiments. These experiments are meant to be relatively cheap so many people and organizations can afford to develop an experiment for the space program. There are specific sizes and power requirements that the experiments have to meet. These are not new and many high schools, colleges and industries have participated in Nanolabs already.
- So far most of these Nanolabs have been specially designed for a very specific experiment. That will probably remain so for many future experiments. However, there are a lot of groups interested in doing an experiment in space but are daunted from doing it because they have to first develop the Nanolab platform for their experiment. This development can take a long time especially if you don't understand all the requirements related to zero-g and the ISS.
- NanoRacks would like to partner with HUNCH students to develop a more generic Nanolab that would allow for a variety of experiments so people could concentrate more on the experiment they want to do rather than on the development of the Nanolab cube for their experiment.



Important General information about all Nano Labs

- All Nano Labs (modules) will be installed into a NanoRacks frame —up to 16 Nano Labs to an ISS Locker. This ISS Locker will travel up to the ISS on a supply vehicle and will be removed from the supply vehicle by an astronaut and placed in one of the EXPRESS racks on the ISS where it will be turned on by the astronauts. All of the Nano Labs inside the Experiment box will run autonomously for about 30 days. After that time, the astronauts will remove the Experiment box with all of the Nano Labs inside and place the Experiment box into a vehicle where it will be returned safely to the ground or be burned up in the atmosphere. You should expect that your Nano Lab will never be touched by the astronauts. All of the actions inside the Nano Lab will happen with out human hands. All of the data must come from the Nano Lab and into Space Station computers without human hands.
- All Nano Labs have to be sealed to prevent any contents of one experiment from contaminating another experiment or the living space for the astronauts. This also means there is little if any air exchange between the Nano Lab and the astronauts atmosphere.
- All electronics give off heat when in use. Heat transfer does not happen as fast in zero-g since there is no convection without fans to move the air. Heat transfer by conduction (contact between objects) works well. All of the NanoRacks modules will be cooled by air being blown into the ISS Locker from the EXPRESS rack. The exterior of the Nano Lab is made of aluminum and is a good heat conductor but the more plastic against the interior walls of the Nano Lab the slower the heat will transfer.





Some difficulties about Growing food in Space

- Although growing a dozen or so plants in space seems to be done fairly easily as NASA and scientists put time and effort into understanding the needs of plants in zero-g, growing enough food in space to feed someone on a regular basis could be problematic at best.
- Consider that if you wanted to feed your crew of astronauts one cucumber per day for a year, it would take around 25 cucumber plants. Not all of them need to be growing at the same time but it takes around 60 days to grow a cucumber from seed to eatable cucumber and can produce 10 to 15 cucumbers. The crew would have to have at least 4 to 5 plants growing all the time at different stages of development and hope that none die or have problems.
  - What do the astronauts do with the dead plants afterwards? On Earth they rot and degrade into the soil thanks to fungus, bacteria and bugs.
  - Is pollen or debris from the plant a problem floating around in the space craft?
  - How much volume do these plants require for growth?
  - How much volume do I need for any of the other vegetables that need to be grown?
  - How many garden modules do I need to grow enough vegetables for 4 to 6 people?
  - How much time does the crew need to spend gardening to keep all of these plants cycling so there is enough food for everyone every day?
  - Once the vehicle gets to Mars, what happens to the plants and the grow cycle if they go down to the Mars surface for a couple of weeks? Does someone have to remain on board to tend the plants while others perform the Mars surface mission?

These are not questions we need to answer now.

Other options for growing food

- As you can see there are quite a few difficulties that will need to be answered for growing food for long trips. There are other things that could be grown in space besides food that could be very helpful to the astronauts. This is not to say that growing enough food in space to feed the crew is impossible. It means that there are many challenges that we have to work through. I suspect that the food that is grown in space is meant to augment the prepackaged and prepared food that is sent.
- The point that is important to take away from this thought experiment is that we need to think deeply about what can be done with the technology that we have and to diversify how we attack the problem.
- That said, not everything that grows and is eatable is a plant. Although mushrooms seem to grow similar to plants, mushrooms are more similar to animals than plants. They grow in a different media than plants and breath oxygen. Many fungi are symbiotic with specific plants where both organisms get something out of the relationship. By eating dead material fungus helps supply water and minerals to the roots of the plants while the plants supply carbohydrates and vitamins to the fungus.

Fungus NanoLab

Problem:

Scientists and Researchers are wanting to send up experiments to the ISS but they don't have enough experience designing labs. HUNCH wants to make it easier for Researchers to do their science without having to do all of the engineering by making a generic lab that is easier for them to work with. Molds and fungus are found growing on the ISS and the crew cleans the station often to keep them from proliferating but few have tried to grow mushrooms yet. As people expand into the solar system, fungus will come with us whether by design or accident. Studying how it does and does not grow in zero-g and the spacecraft environment may be important to the health and safety of the space craft and crew.

Objective:

Design a generic lab for growing fungus that can be arranged by different researchers to fit different fungus experiments

Requirements:

- Must fit within a 10cm x 10cm x 20cm NanoLab.
- Accurately Account for the volume and a variety of locations for the hardware (cabling, camera, sensors, raspberry pi,…) to be installed in the box. Each item may not have a specific location but can be shifted to where the researcher wants them. (think of it like designing a doll house so that a child could arrange the furniture and accessories where they want them to play they want)
- Determine materials for holding the substrate—plastic bag, cloth, rigid container, size, shape—cylinder, rectangular
- Determine methods for injecting water to start the growth after the lab arrives on orbit and turned on.
- The researchers want to be able to arrange and place their substrate in a specific location relative to the camera(s), the water injection, and sensors. It is important that your team makes the NanoLab variable enough that the researchers can locate what they want where they want and be assured that nothing will shift or move during vibrations of launch or while on orbit.
- Find a good location for the control electronics that won't get wet but will allow good options for cable routing for the sensors and camera(s)--may need contact with aluminum NanoLab wall for conducting heat from electronics.
- Design a method of stopping a mushroom from releasing spores—this could mean preventing the cap from opening to prevent spores from being released—not too early, not too late. There may be other options for preventing spores from releasing.

Pointers:

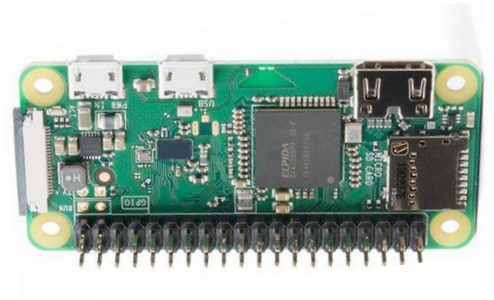
- This will have some similarities to growing a plant but the lighting may only be for photography.
- Is infrared lighting of any value for the mushroom? Do you need a specific camera?
- Is there value to Ultraviolet light?
- Since these experiments will only be for 30 days and the box is mostly sealed, it seems one injection of water is all that will be required—may find different with experimentation—determine by testing.
- There are many ways to cut a mushroom but what direction will it grow?
- Mushrooms seem to sprout up in the yard overnight. How will you know when to cut it?
- Will mushrooms grow bigger or smaller without gravity?
- Know the dimensions of your equipment from the website. Don't forget cabling.
- How do you keep the cables from vibrating out of sockets or getting in the way of the camera?

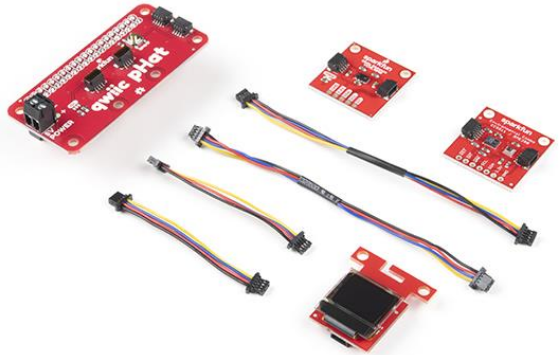
Hardware to consider

Fungus NanoLab

- Raspberri Pi Uno or Arduino
- Temperature sensor
- Humidity sensor
- O2 sensor
- CO2 sensor
- Infrared Lights?
- Visible lights for taking photos?
- Infrared Camera(s)?
- Motor(water distribution)
- Motor (cut cap off mushrooms)
- Motor drivers

These are a few of the sensors and equipment that should be considered for your lab. You are trying to develop a NanoLab that many people could use to do their research with and not have to alter it significantly. It is impossible for your team to be the 'everything lab' for every researcher but try to give as many options as possible. There are limits for how many things can be in this confined space and still have enough room for mushrooms to grow. Remember to include cables and motor drivers as needed. There will be cables and they will need to be held down so they don't vibrate loose during launch and then get in the way of cameras or get cut like the mushroom.

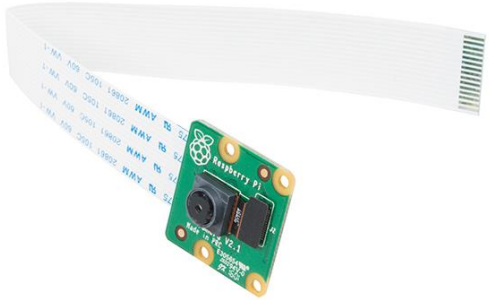


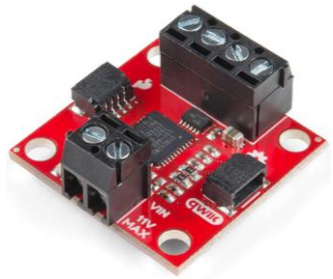


Read through the NanoLab GUI to understand the other team's responsibilities.

Your job is to show a variety of ways how all the parts can be arranged inside the NanoLab and how they will attach so they don't vibrate out of place during launch. It is important for you to show where the lights, camera and other electronics go and even how it will look but you are not doing the programing. That will be the job of the students who are developing NanoLab Software GUI.
It is your job to work the mechanics of the how the NanoLab will function but still allowing room for the researcher to be creative(kind of like Legos-make it so you can do many things, not just one experiment).

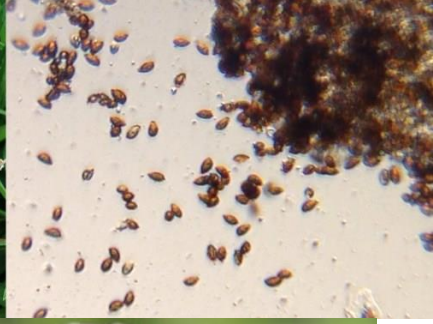
HUNCH can not afford to send everyone a Sparkfun Kit—only the GUI teams. In the table you can see the dimensions of many of the components that researchers may want to use. I found the dimensions on the Sparkfun web pages for the part (usually under features). You can get more detailed information for each of the parts from the Sparkfun website. You may also find other components that you think would be valuable for your NanoLab.

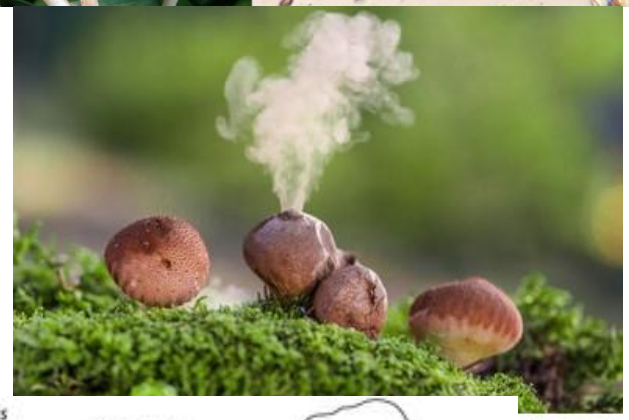




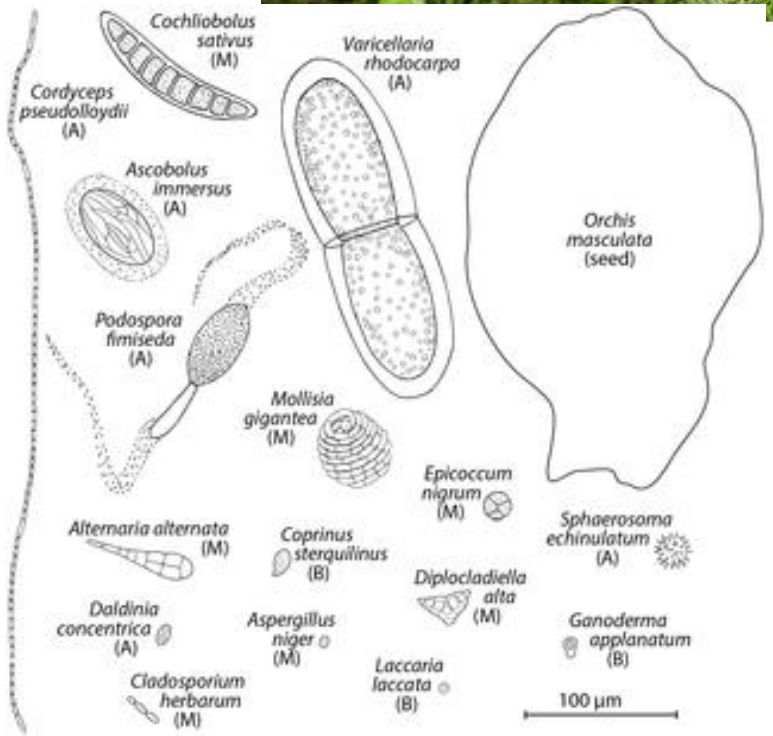
SparkFun Part Number	description	Qty	Notes
PRT-08430	Jumper Wires Premium 6\" F/F Pack of 10	1	155mm +/-5mm long, 26 AWG
TOL-13831	5.1V DC 2.5A Wall Wart (USB Micro-B)	1	AC to DC power supply
DEV-14028	Raspberry Pi Camera Module V2	1	25mm x 23mm x 9mmc, 15cm ribbon cable
PRT-14272	Pi Zero Camera Cable	1	
CAB-14274	MiniHDMI	1	
CAB-14276	USB OTG MicroB Cable	1	
PKG-14011	Large Red Box (9.25x6x2)	1	box it comes in
COM-15052	SparkFun Noobs card Raspberry Pi	1	
DEV-15470	Raspberry Pi Zero WH	1	65mm long x 30mm x20mm
ROB-15451	SparkFun Qwiic Motor Driver	1	25.4mm x 25.4mm x 12.5mm
PRT-16662	Jumper Wires Premium 6in. M/M Pack of 2: Red and Black	1	
WS2812B	SparkFun RGB LED Breakout - WS2812B w/ Headers	1	24 mm x 22mm x 5mm
KIT-16841	SparkFun Qwiic Starter Kit for Raspberry Pi	1	65.00mm x 30.5mm x 10mm
ROB-10189	Servo - Generic Continuous Rotation (Micro Size)	1	42.8mm x 33mm x 16.5mm

Spores in Space





- Plants grow toward the light—even in zero-g. Mushrooms grow in the dark. What direction will mushrooms grow in zero-g? Will they grow in the same shape as on Earth?
- Different types of mushrooms have different shapes and also grow at different rates.
- Spores are the reproductive cells of the fungus. They are very small and can float away and spread in the slightest of breeze. Spores from mushrooms can be too small to be removed from the air by way of HEPA filters. Depending on the type of fungus flown and the material it eats, it is unlikely there are places that the spores would grow on the inside of the ISS, however some could cause problems with the astronauts breathing. Although the Nano Lab may be closed up, the spores are very tiny and may be able to get out. We don't want spores from a mushroom to get out. We don't want fungus growing out of control in places on the ISS. The spores are only released when the mushroom cap opens all the way. Part of your design must include a way to stop the growth of the mushroom before the spores are released. This may include cutting the mushroom or some other method.
- **Must be able to stop mushroom growth before the cap opens and can release spores. –cut cap off?—other options?**
- **Will the fungus/mushroom keep growing if the mushroom cap is cut off?**



Mold and Fungus on ISS

This is a cloth covered panel that grew mold where wet towels were placed to dry after crew cleaned up. The mold is similar as to what you might find in your bathroom but there is no way to open a window and let the fresh air blow through the house to remove spores. Eventually the panel was replaced with a new panel.

This is a clogged water line on the ISS that was contaminated with some kind of mold or fungus. The ISS uses iodinated water or silver biocide in its water to prevent this from happening. This line was discarded and a new line was installed.

Samples are taken on a regular basis on the ISS to find out what kind of fungus is on the station. The crew clean the ISS on a weekly if not every day to keep generic molds and fungi from growing. This is a sample tray where astronauts swab areas in specific areas and allow the samples to grow so we know what kind of fungi are present and where crew need to clean.

These are all reasons we are trying to be very careful with not allowing spores to spread from a fungus experiment.

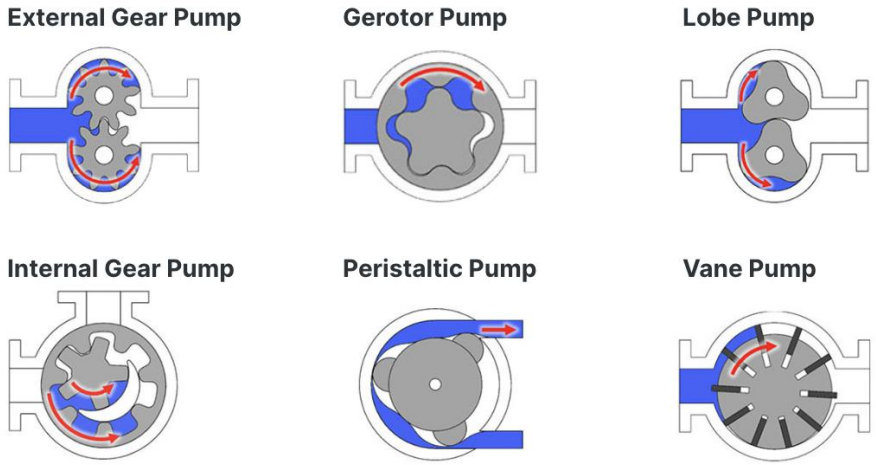
Substrates for different fungi

- Not all mushrooms grow in the same material. The researcher will need to choose the kind of substrate that they need for the fungus they are growing. It will be important for you to
  - determine what will contain the different types of substrate—plastic bag, rigid container that allows visibility of the growth of the mycelium,… other
  - How to hydrate the material—pump, capillary action, compressed water bag—valves?
  - How to hold the substrate in one location—Velcro, structure inside the NanoLab
  - determine where the mushrooms will grow from the substrate container—one or two specific openings or does there need to be more air available for the mycelium growth
- Substrate can be dry at launch then once it is wet, the fungus will start to grow
- The researchers may want to send up spores or spawn—are there differences for the containment?
- Substrate material—goes up dry, moistened when on orbit
  - Wood pulp
  - Grains
  - straw
  - Fecal material
  - Nut hulls
  - Others

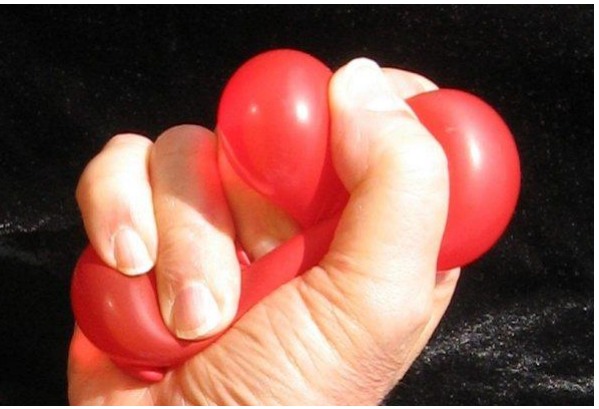
Water injection—keep it simple

Could you put gear teeth on the edge of the plunger and drive the plunger with a servo motor?

Capillary action from a plastic bag through a string. How do you prevent it from flowing before it gets to orbit? How do you start the fluid flow once the lab is set up?



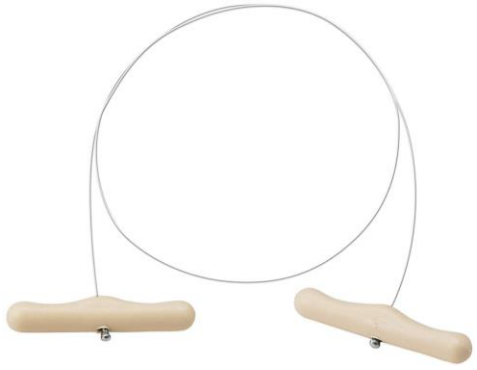
There are a lot of different kinds of pumps that can be driven by motors or servo motors.



Could you put water in a balloon or plastic bag and compress it with a motor or a spring? Valve for start and stop?

How do you inject the right amount of water?
The NanoLab is mostly sealed so there won't be much evaporation of water from the NanoLab.
pinching a tube with servo motor

Cutting a mushroom



A good method for cutting the mushroom is needed so that it doesn't release spores but we also don't want the cut mushroom cap to get in the way of the camera(s). There are plenty of sharp blades that can cut the stem of a mushroom (soft but a little spongy and slightly fibrous) and there are plenty of wire cutters that can cut through mushrooms. The question to work on is how to activate the cut and use as little volume as you can so that there is room for your mushrooms to grow. Many of the blades are much wider than what may be needed. Keep your blade size appropriate for the job so you have room for all of your needs.

- Motors and springs can be used to rotate a cutting blade.
- A spring could expand or contract to cut the mushroom like a guillotine.
- A motor could reel in a wire or nylon line and constrict against the mushrooms to do the cutting.
- What if a wire was sharpened on one side so it is a partial blade?

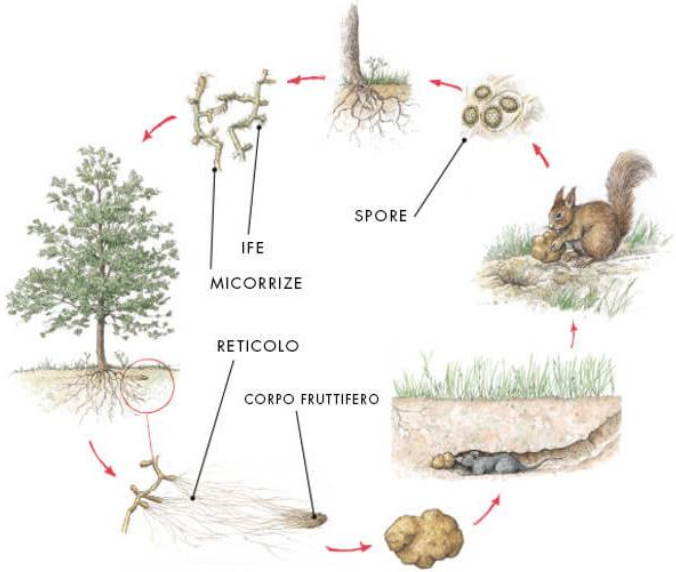
Notice that these mushrooms were harvested before the cap opened—no spores

Here are some questions that may help you with researching mushrooms:

- The more you understand about how fungus and how mushrooms grow the better you will be able to design the NanoLab that researchers will want to use.
- How long does it take for mycelium and mushrooms to grow?
- Do all fungi produce mushrooms?
- Do all mushrooms produce spores?
- Are all spores the same size and can be filtered out of the air?
- Which fungi are eatable?
- Which fungi should be kept out of a space craft because of toxicity?
- How much air do fungi need to grow? How long can they grow in the volume of a NanoLab?
- How big of a ball of substrate is needed for the fungus to grow?
- How much water does a fungus need to grow?
- Is the size of the mushroom determined by the size of the mycelium?

Fairy rings are a fungus that started as a spore and is growing outward as it consumes decaying mater. They often show up after a rain. Some fairy rings make the grass grow better and others can kill of the grass as it grows.

There are many different kinds of bracket fungus that grow on decaying wood. Many are eatable but need to be cooked.



Truffles are a symbiotic fungus that grows on the roots of some trees and are used in high end gourmet foods. They can cost over $1100 per pound. Could they be grown in space as a natural flavoring for astronaut food?

I highly recommend ‘Fantastic Fungi’ on Netflix. I never knew fungus could be so amazing.

Things to consider

- What type of Infrared camera?
- Can you see the mycelium growing?
- What kinds of mushrooms can we grow? What kinds do we want to avoid growing in space?
- How will you start the growth once it gets to orbit.
- How do you hold the mycelium and growth material so it doesn't float around in the box?
- What material options are good for different fungus to grow it in?
- If growing mushrooms, how to make them grow in a specific location?
- Slime molds?
- http://harvardsciencereview.com/astromycology-the-fungal-frontier/
- https://www.nasa.gov/feature/ames/myco-architecture
- https://www.youtube.com/watch?v=cApVVuuqLFY

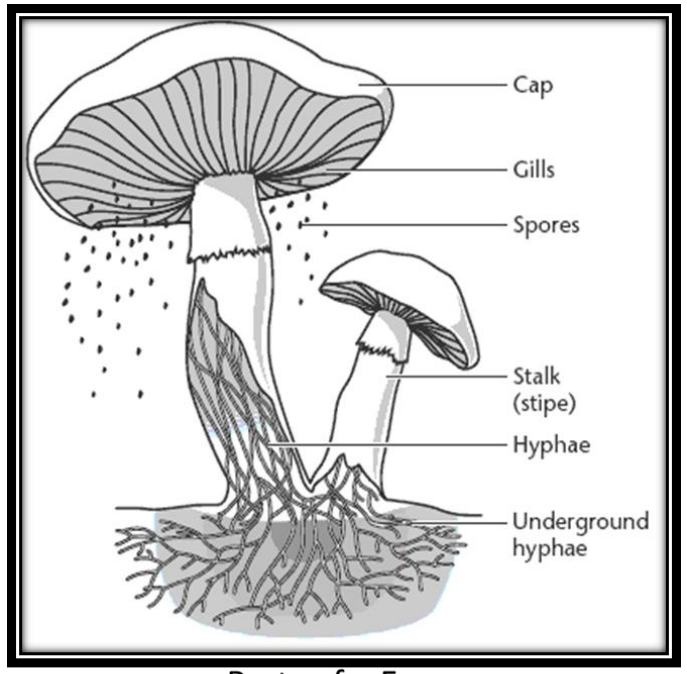
Science Tips that may be valuable to study:

- Bioluminescent fungus—does the amount of light change depending on factors related to gravity?
- Some mushrooms make vitamin D when exposed to ultraviolet. How much UV do they need

Engineering tips

- Since there will be a limited amount of oxygen in the NanoLab, and the fungus grow with O2, this may be a limiting factor for how long the fungus would grow in the limited space. Would it be possible to inject O2 into the Nano lab so there is less nitrogen and CO2? This could allow it to grow longer.
- How could the O2 be increased without getting too complicated?
- At some point in the future there may be a time when a researcher puts both a plant and a fungus into a NanoLab but that will be a different project.

Life Cycle



Parts of a Fungus