

Fabrication Guide

| | |
|------------------------------|-----------|
| Introduction | 1 |
| Containers | 2 |
| Growth container | 2 |
| Insulation | 3 |
| Heating | 3 |
| Nutrients container | 4 |
| Water container | 4 |
| Mechanical components | 5 |
| Pumps | 5 |
| Filters | 8 |
| Electronic box | 9 |
| Sensor module | 10 |
| Electronics | 12 |
| Software | 13 |
| Spirulina propagation | 14 |
| First steps | 14 |
| Water source | 14 |
| Medium | 14 |
| Extraction | 14 |
| Parts list | 15 |

Introduction

This guide is for the construction of the spirulina bioreactor (project named : FFF_Free_Food_Forever). The fabrication of this system is not a simple task and has not been optimized for user friendliness. As the project stands now, anyone with very basic electronics and informatic know-how should be able to build it by themselves following all the steps described in this guide. Because this is an open source project, any missing steps and additional information can be added by anyone.

The skills required for this project are as follow :

- Identify and purchase electronics components with the right technical specifications, part number, model number and physical dimensions.
- Electronic soldering of wires, connectors and very small components.
- Downloading softwares, documentation and files.

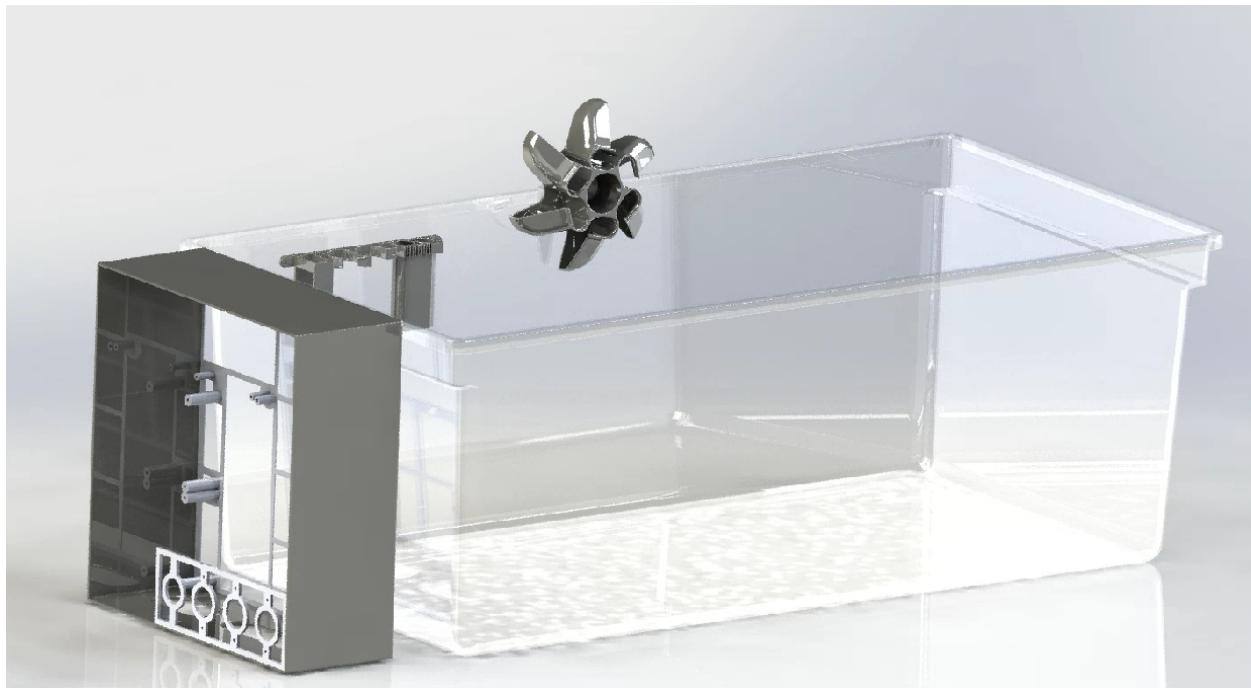
- Modifying some line of text in the code to set up your system for your wifi network
- Using the Arduino IDE to upload a given code to a microcontroller
- Understanding of voltages, current, watt and the safety related to manipulating electric components.
- The use of a 3D printer or being able to build the structural parts manually out of some wood or plastic.
- Connect wires properly following instructions.
- Make a purchase of a Customized PCB on JLCPCB.com or any alternative source using the provided model files(.gerber)

If none of the above frighten you, you should be able to make this work with some trial and error and perseverance. I believe anyone could do it with enough patience, but it might get very hard for some people to do some tasks.

Containers

Growth container

For the final culture, you will need a 100 L container or more to get approximately 20g of dried spirulina per day. Any non-toxic plastic container will do. To start the culture from a starter kit or a borrowed sample of live spirulina, you will need several containers in order to progressively expand the cyanobacteria population. First a 4L bottle progressively filled, then a Large bucket and then bigger containers.



Insulation

The growth temperature for the culture is between 25°C and 35 °C. Depending on the ambient temperature, insulation might be optional. However, a soft material should be placed between the heating pad and hard surfaces to prevent any damage and help direct the heat towards the culture. More insulation means less heating and less electricity used.



Heating

There are a few options to heat up the culture. The one I settled on for its price, safety and simplicity are floor heating mats. Place the heating element on top of something soft like insulation pads. Two layers of floor heating will be needed if they are rated for 220v and you can only plug them in 110v. They will need to be plugged in parallel. Sliding the wire between the copper and the plastic is good enough, but use better connection method if you can.



Place the container on the heating mats and make sure they are not bent or in contact with a sharp corner.



Plug in the heating element to verify it is working properly.
You can surround the sides of the container with more insulation.

Nutrients container

The culture will need more nutrients as it grows and as it is consumed. The system should automatically add some from a reserve of concentrated nutrient mix. Any plastic container will do. Pierce a hole the size of the tubes in the cover and put the tube into it. To avoid the pumps sucking up chunks of materials, adjust the tube so its end is at some distance from the bottom.

Following a nutrient recipe, fill the container. The code might need to be modified to provide the right amount of nutrient to the spirulina if the recipe used doesn't have the same concentration. A variety of recipes are available online. To use the simplest one, measure 9ml of salt, 10ml of salt and 1.3 ml of fertilizer. You can print and use the custom measuring spoons provided. This amount of powder is for a 4 liters culture. The Automatic nutrient distribution code requires this same amount of powder to be dissolved into 500ml of pure water. The system will provide this concentrated mix to the culture at the correct rate for the spirulina extraction that it is doing.

Water container

Because the culture is quite warm at 35°C, there is a lot of evaporation and condensation that will happen. To avoid mold to form in the condensation, a good aeration of the container is the simplest solution. As evaporation occurs, the system will add some pure water to the culture.

Any plastic container will do. Pierce the lid for the tube to fit in and push it to the bottom of the container. Fill it with clean demineralised or distilled water.

Images

This container could be filled automatically with tap water, but the need for this water to rest until no chlorine is left make it more complexe. It would require an electronically controlled water valve, a water level sensor that can detect when the container is full and also completely empty. The code would also need to be written.

For now, filling the container back up manually whenever it gets empty is required.

Mechanical components

This section includes the pumps and the filter. At the moment of writing this guide all parts can be installed, but the code for their automation requires more work.

Adjustments are continuously made and this notice will be removed when they all work well with no interventions. Most of the code is there and they can be temporarily activated manually via the web interface.

Pumps

Four pumps are needed for the complete automation of the system. 3 peristaltic pumps and an air pump. The 3 peristaltic pumps move liquids around and the air pump provides aeration and mixing of the culture.

To help with the simplicity of the code, use the same tube diameter for the extraction and the nutrient pumps. This will allow the ratio of nutrient to extraction done to be time based instead of volume based.

These Pumps can be used for other purpose, for exemple, to slowly transfer the whole culture from one container to another for cleaning or to increase slowly the volume of the culture while its being started.

To install the pumps, follow these steps.

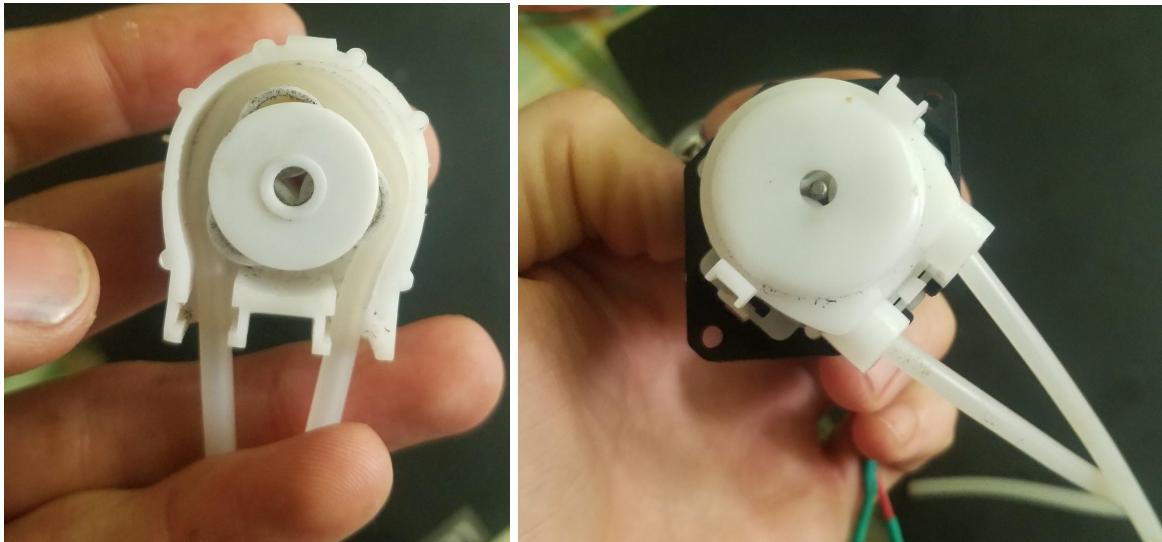
Solder the wires to the pump motors. Use the proper color for the proper polarity for less confusion at a later time.



Images

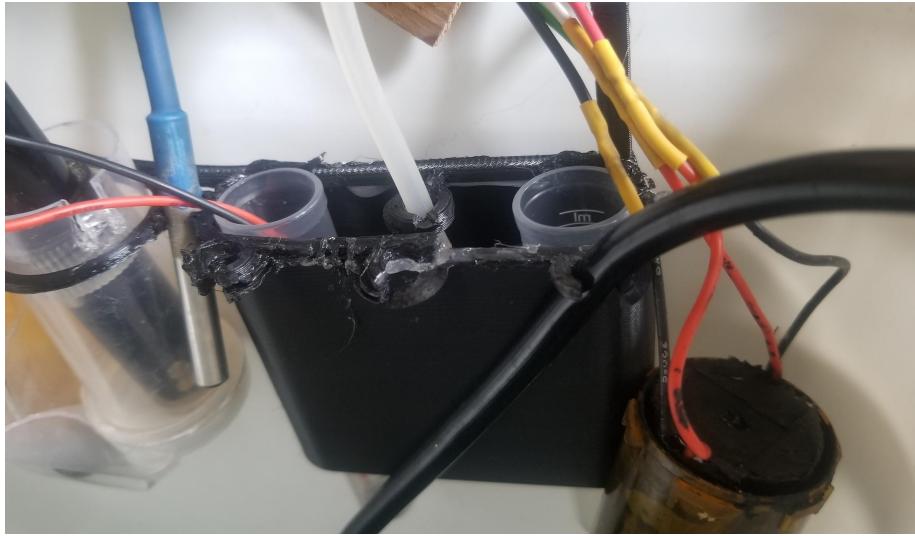
Tin the other end of the wire for a more rigid tip. Wires should be more than 150mm long, but their size can be shortened at a later time for better cable management.

Pass the tubes in their mechanism if they aren't already.



Power the pumps to test the direction of the flow. A 12 volt power source is needed for the pumps listed. Marking the direction of the flow on the pump housing can be useful, but consider that the flow could be inverted when reversing the motors wires.

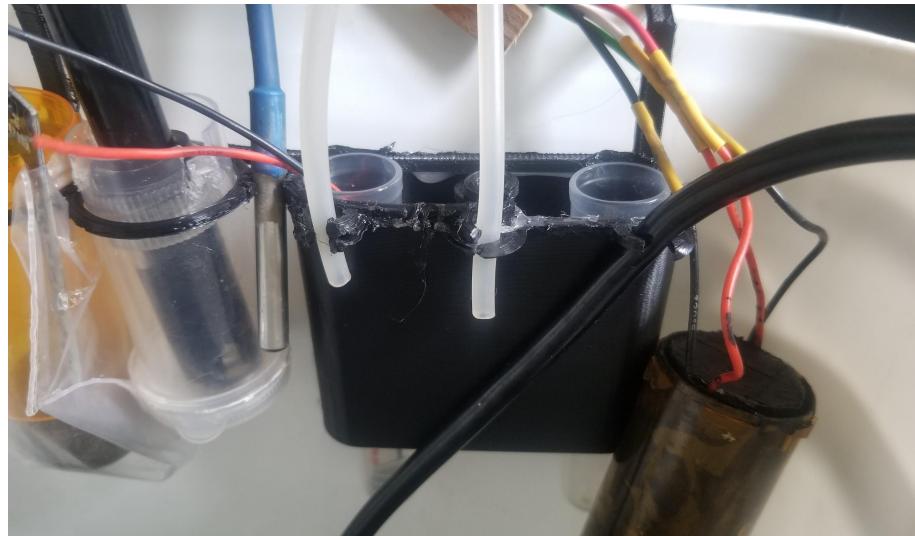
The extraction pump tube's sucking end needs to be placed in the density sensor chamber. This chamber is closed and need this additional movement of water to produce more accurate readings.



The water and nutrient pump's tube's sucking extremity should be in their respective containers.

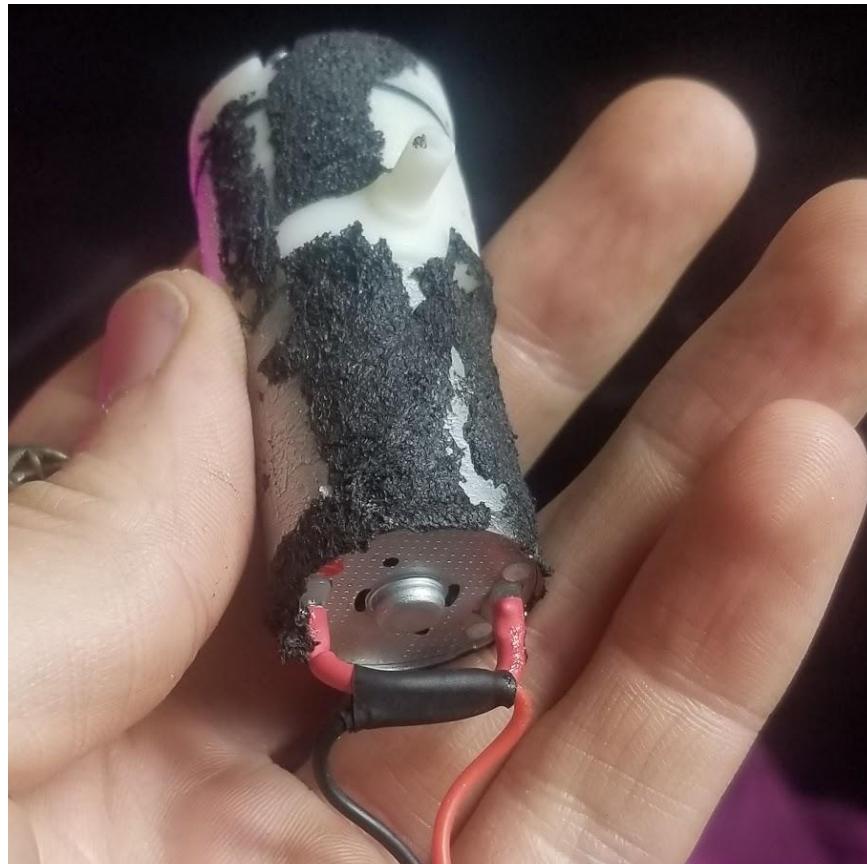
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The other end of these two tubes should be placed in their clip socket in front of the density sensor chamber.



The outlet of the extraction tube will be placed in the filter when it is installed.

Solder 2 wires to the air pump.



Plug in the tube for the air pump to its outlet and plug the other end of the tube to the airstones.

Images

If a pierced tube is used as an airstone alternative, fill up the tube with coarse sand to add weight. Make sure to remove all magnetite from the sand using a magnet. Inserting a metal rod entirely covered with plastic in the tube can make it rigid enough to keep the tube at the bottom of the container. Culture medium will seep through the holes into the tube and will corrode any metal that it touches, potentially poisoning your culture and killing all the spirulina.

Images

Filters

The current system is the most basic and simplest option. The extraction of the spirulina is done by moving liquid to a filter that resides in the same container. This way, the concentrated spirulina stays alive and fresh while it's there and continues to multiply. This method is not as clean and sustainable as draining and replacing all the waste water of the extraction. Doing it this way will require more cleaning of sediments and might continuously shift the pH of the culture into bad levels. Because the water isn't removed, the addition of nutrients will be limited by the evaporation.

This part is not programmed yet.

The 3D model for the filter is not finalized. A simple reusable coffee filter can be used or 20 μm nylon mesh can be purchased to make your own.

Place the filter in the main container to allow the medium to fill it. The mount for the filter are not modeled yet. Use creativity to attach it to the side of the container.

Images

(once the model is ready :)

The filter is made by gluing a 20 μm food grade mesh to the 3d printed frame. Use hot glue, low heat soldering iron, epoxy or crazy glue to attach the filter to the 3Dprinted frame.

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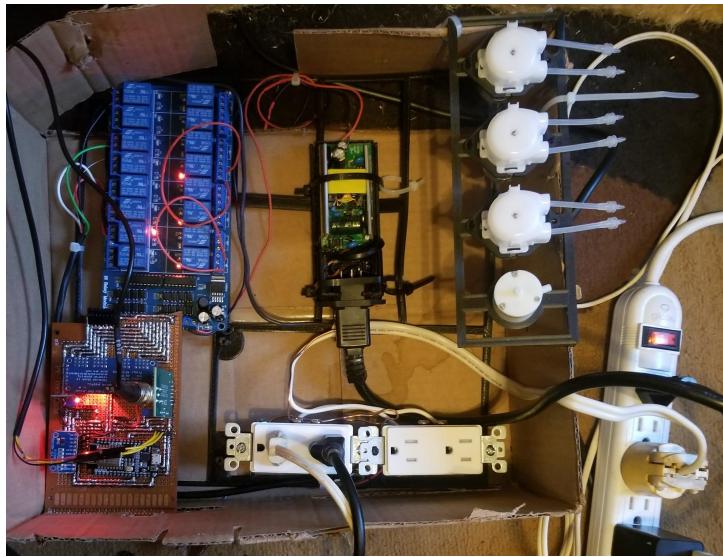
Electronic box

Any container big enough for all the components will do. Make sure there are no loose wires and that no heat source is near the pH module. Make sure all the 110 v wires are safely secured, ideally using certified electric boxes and wires.

Alternatively, you can print the box designed for this system and assemble it.

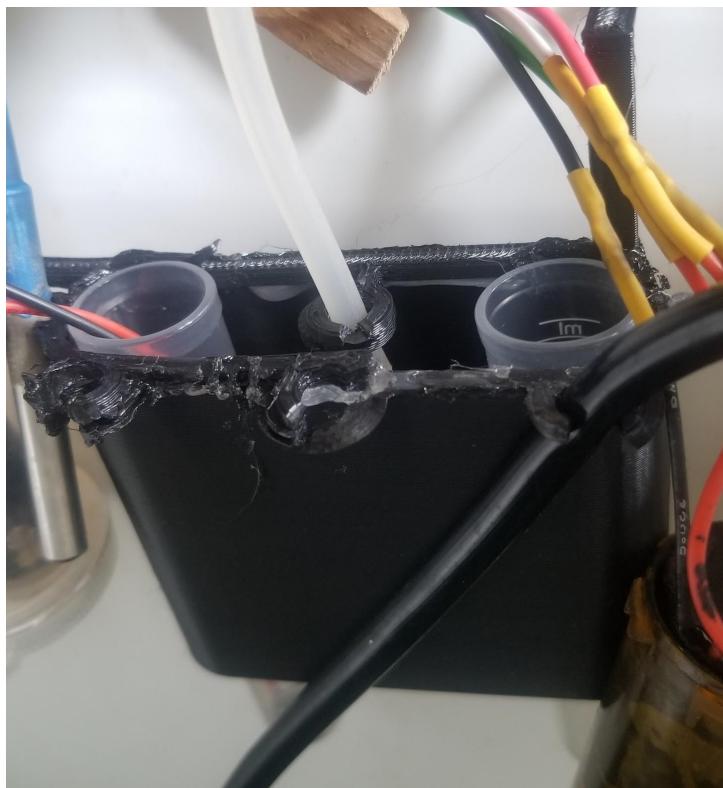
Place all the electronics inside, first the relay board, then the motherboard.





Sensor module

The sensor module is the part that needs the most manual work.
First, place the test tubes in their places.



Then slide the LED and the photoresistor in each of them, facing each other.
images

Secure all the tubes in place and place the density sensor cover on top of it. The density of the culture is measured by measuring the amount of light produced by the led that can reach the

protoresistor. Complete darkness is needed for accurate measurement. Thus a cover need to be placed.

Images(not modeled or printed yet)

Cut the bottom of two pill bottles. The yellow one if for the water level sensor and the other one is to give a spirulina free container to the ph meter.



Cut a medium ziplock bag in dimensions shown in the picture. Giving some slack around the pill bottle. Place the bagged pill bottle in its socket and secure it. It will need to be filled with slightly salted water when in place. Place the level sensor in its position, placing one lead inside the bottle and the other outside the bottle while inside the bag. Because the culture is too corrosive for the sensor, it will instead measure the level of the liquid that is inside the ziplock bag. This liquid needs to not be in contact with the electrodes while it's not submerged. The water inside the bag will rise with the culture medium, allowing it to contact the electrodes at the same height.

For the second pill bottle, secure a thick filter around the base with a ti-rap. Secure the bottle in its socket. (this container is not good enough yet to avoid spirulina to get into it. The presence of biological material in contact with the ph-meter bulb disturbs the measurements. It does need much improvement before being reliable.)

Images

Place the sensor module in the container.

Place the thermometer in its socket



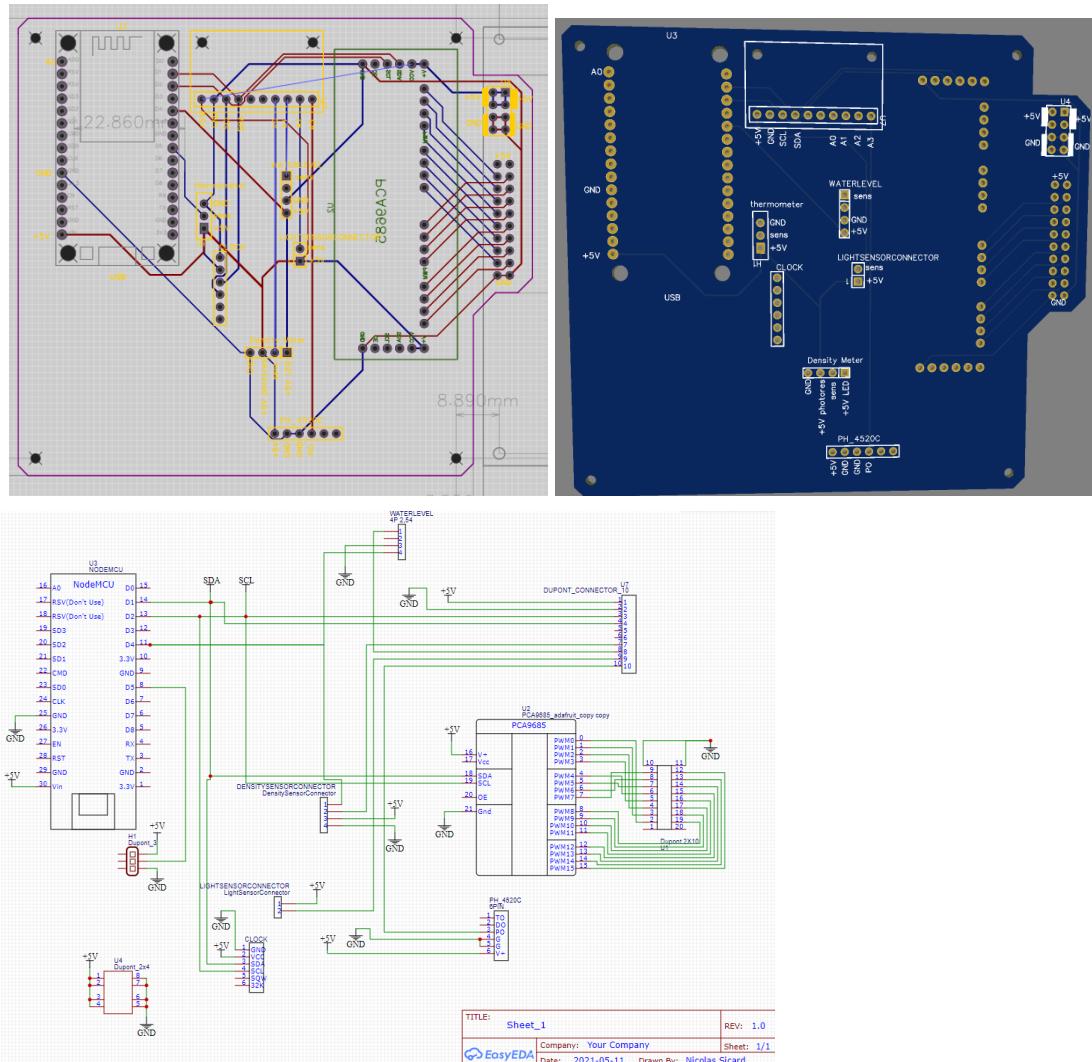
DO NOT ~~place the ph sensor in its place until it is filled with liquid.~~ The end of the ph sensor must never dry out. Alternatively, leave the storage liquid vial on it.

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Electronics

Plug in every board in their specified locations. You Absolutely have to verify that every pin label on every board corresponds to every pin labeled on the motherboard. It is entirely possible to wire all the modules together without the motherboard. The board is only to help avoid mistakes and make the process easier and faster.

Wire the pumps and the power outlet to their proper relays as well as the power supplies to the right devices.



Add resistor on thermometer (mais encore?)

Software

Once every component is plugged into place, you can plug the usb into the node mcu board and into your pc.

The programming steps are as follows

- Install arduino ide
 - Install libraries (at some point no libraries will be needed as they will be included in the downloadable file)
 - Add library urls into the preferences.
 - Download nodemcu board managers
 - Download the modified interface library and replace the original one in the right folder.
 - Download the microcontroller code
 - Modify the code to include the right wifi name

- Test the boot of the module with the ide monitor display
- Find the right Ip address to access the interface or modify the code to set a fixed ip.
- Verify that the intern clock correspond to the real time.

Image of
a colorful diagram of the different
code sections for better navigation

Spirulina propagation

First steps

Unless the system is ready to run, put the spirulina in the freezer.

Prepare a growth medium following recommended instruction for the spirulina strain acquired. To allow the culture to keep a proper density, split the main container in some parts with plastic film or barriers. Place the end of the extraction tube going to the filter into an unpopulated section. This will allow to propagate into the second section slowly as the first one get denser. (using an empty bag as the second section will allow to keep good density in it as the volume grow.)

Water source

There is nothing that you can do to help a culture survive if the water used is full of minerals or has a pH different than 7.

Medium

Until I find a good homemade medium option, purchase proper medium powder.

Extraction

The extraction will be done automatically, putting the excess spirulina of the culture in a mesh. Take out the mesh and rinse the spirulina in the sink in the same mesh.

images

Then put the biomass into a glass, add water and stirr for a more uniform look.

This tastes nothing at all, has no smell and no texture. The cells don't need to be broken, it doesn't need to be dried or cooked or crush. None of these methods improve bioavailability. They only release the taste trapped in the cells and allow oxidation of the molecules.



Parts list

Amazon carts
Aliexpress carts
other
3D prints