PLANTS & MACHINES

robotic ecosystems workshop

Innovative Citizen
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THE FAMILY

Growing population and urbanisation

- global population will grow by 3 Billion until 2050
- most of us will live in megacities
- a lot more food needs to be produced

Rising demand for crop production

- traditional, soil based agriculture is at its limits
- there is not enough arable land and water to feed the world
- monocultures, the use of pesticides and fertilizer take a heavy toll on the environment

Rising demand for climate independent growing methods

- climate change makes farming a gamble
- we need to reduce the amount of resources used for crop production to slow down the effects of climate change
- we need consistent, efficient, clean and healthy growing methods

Strong technology affinity in urban areas

- acceptance and demand for intelligent technologies rises
- software and hardware have the potential to make a variety of processes more efficient
- smart city, smart grid, IOT, smart everything

Rising demand for fresh and local food

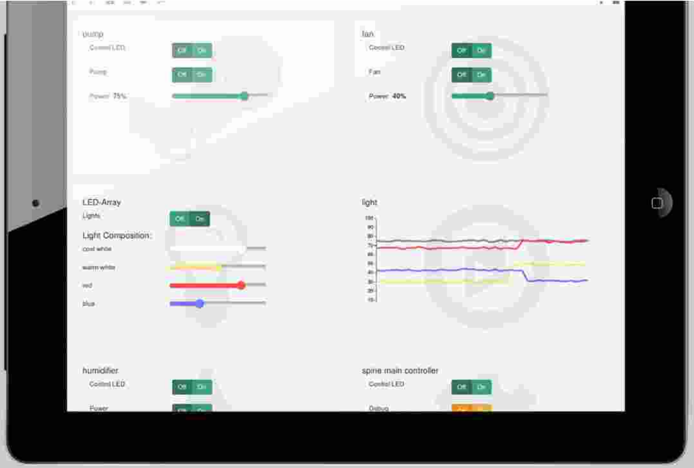
- consumers get more interested in the why and how, they want to know what exactly they consume
- rising demand for local and organic food
- more awareness for health and sustainability

PROBLEMS / CHALLENGES, NEEDS

- urban farms on rooftops or old factory buildings use aquaponic / hydroponic to grow local crop while saving lots of resources
- environmentally friendly production (climate smart agriculture)
- short distance transportation of produce
- automation / precision farming is used to increase productivity per sqm
- greener cities, more jobs

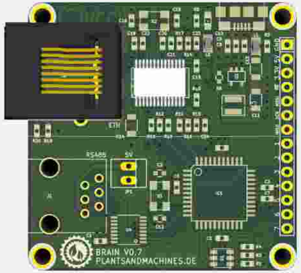
- space in the city is very expensive, urban farms need to be very efficient in order to compete with larger greenhouses
- high set up and running costs limit growth of the urban farming market
- control technology is often cost prohibitive for SMEs in the field of urban horticulture

URBAN FARMING



- we allow farmers on a shoestring budget
  to automate and optimize their growing operation
- artificial intelligence helps growers to find
  the perfect conditions for their crop
- flexible hard and software that adapts
  to the need of the growers and their crop
- all greenhouse data at the tip of your fingers,
  with a sleek, platform independent user interface

PLANTS & MACHINES GREENHOUSE AUTOMATION

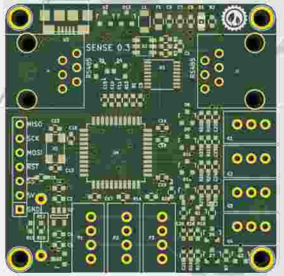


spine controller
5 x 5 cm, RS485, Ethernet, USB

main controller, integrates sensor data and automates actuators

Integrates up to 256 other slave controllers on the RS485 bus over distances of up to 1.2 kilometers.

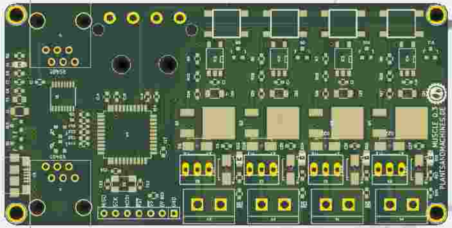
Connects to host computing unit via ethernet.



synapse controller
5 x 5 cm, RS485, I2C, ADC, USB

sensor controller, integrates 7 sensors into the system

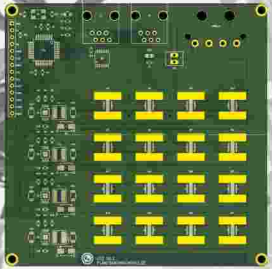
plug & play bus device,
communicates with the spine controller.



muscle controller
10 x 5 cm, RS485, USB

actuator controller, integrates 4 actuators into the system (12V DC, 4A)

plug & play bus device,
communicates with the spine controller.



light controller
10 x 10 cm, RS485, USB

4 channel LED controller, spectrum adjustable grow light

plug & play bus device,
communicates with the spine controller.

The MakerBot for automated indoor gardening.

Automate and monitor self-designed indoor gardens of any type without programming skills or knowledge about electronics.

- first alpha test for our control technology will be smaller scale in form of B2C DIY automation kits
- large maker / diy scene around indoor gardening, hydroponic, aquaponic
- high interest in system automation
- goal is to establish an open source community around our products that helps us with the hardware and software development

OSS & OSHW

DIY KIT

- hydroponic (soil less growing)
- aquaculture (lots of pollution)
- aquaponic (combine the two)
- closed water cycle

AQUAPONIC

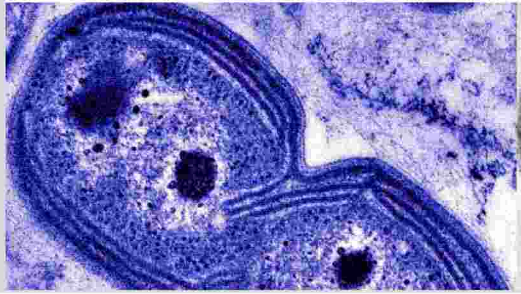
AQUAPONIC ORGANISMS

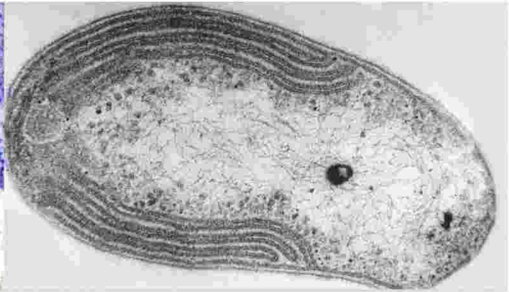
- **fish** (chicken, cows, birds, etc)
  water temperature, dissolved oxygen, water hardness, toxins, PH

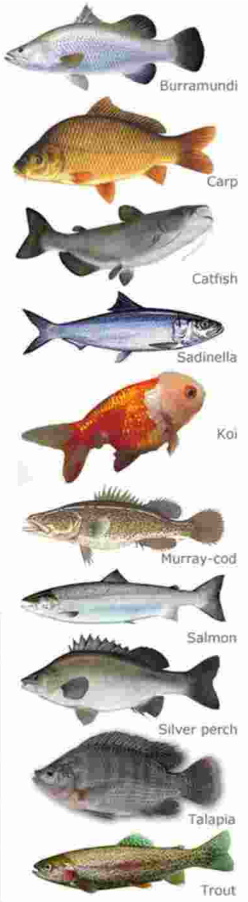
- **microorganisms** (Nitrosomonas, Nitrobakter)
  humid conditions, temperature, oxygen, ammonium, ammonia, nitrite, PH

- **plants**
  temperature, humidity, light, nutrients, CO2, oxygen, water, PH

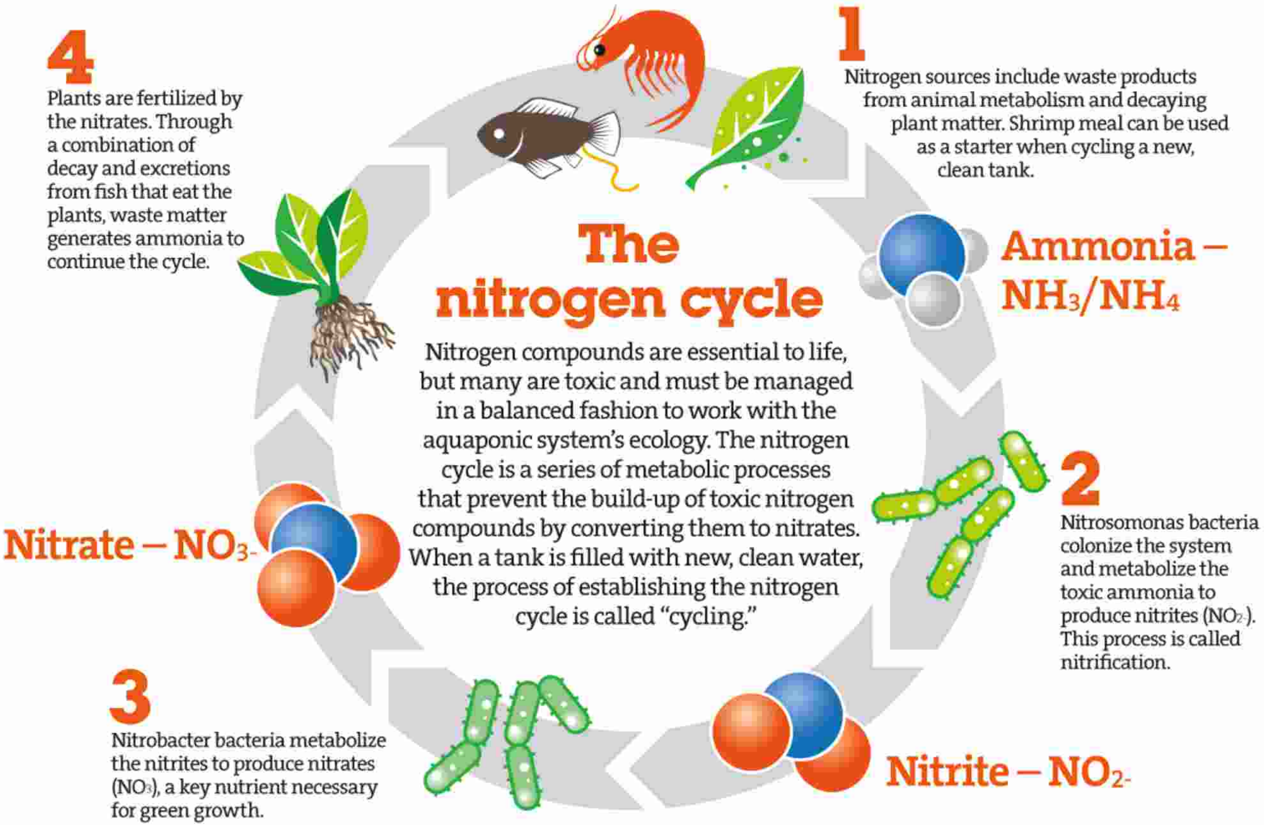
- biggest challenge finding and keeping the balance







- when you find the balance
- nitrification cycle starts
- Aquatic organisms create Ammonium and Ammonia (becomes toxic quickly)
- Nitrosomonas take up NH3 and NH4 and produce Nitrite (less toxic)
- Nitrobacter take up NO2- and produce Nitrate (least toxic)
- plants take up Nitrate
- clean water continues the cycle
- best PH around 6.8 - 7.2



AQUAPONIC NITRIFICATION

- saves water and fertilizer
- totally organic produce
  (no BIO tag for now, no soil)
- does not depend on arable land
- can be done indoors
- resilient against pests and diseases
- year round production
- better for the environment

- not as efficient crop production as hydroponic, but uses less ressources and can produce food fish
- more difficult to handle, have to take care of 3 organisms
- if you have pests or diseases, they are harder to fight

AQUAPONIC PROS n CONS

- nutrients should not need be added when you have a healthy system (deficiencies? -> check system)
- FE2 chelate
- ph buffer in form of seashells
- ph up in form of calcium carbonate and potassium carbonate
- ph down in form of nitric, muriatic, phosphoric acid (beware of anti-bacterial acids)
- adapt system really, really slowly

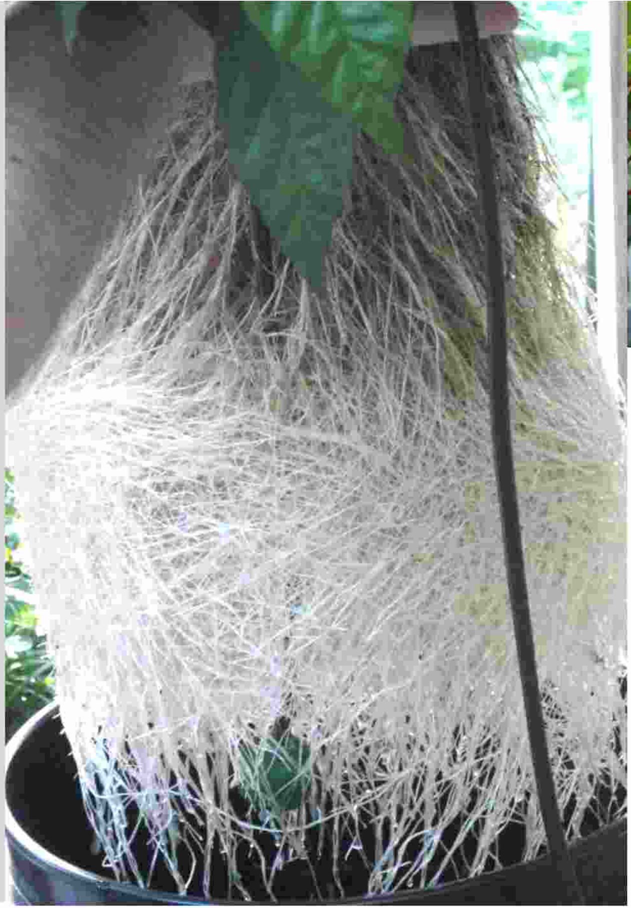
AQUAPONIC ADDITIVES

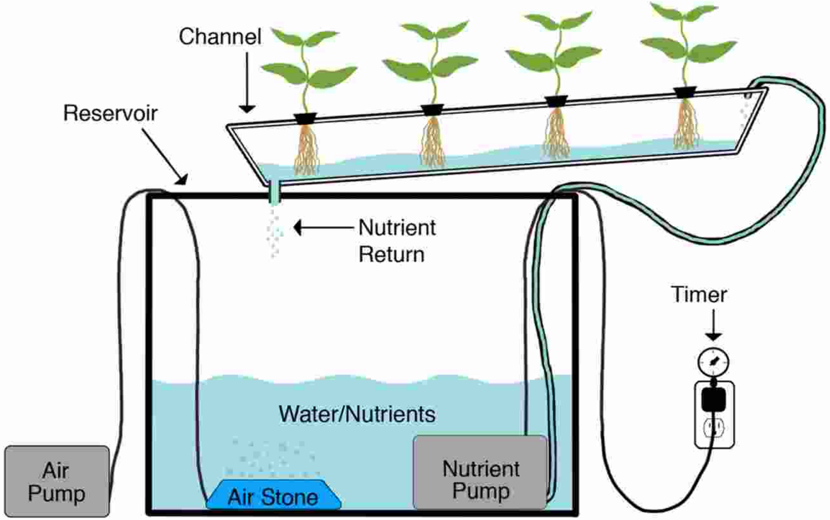
- mostly developed for hydroponic
- with little adaption works for aquaponics as well
- kind of a war going on, which method is the most efficient, all have pros n cons

SYSTEM DESIGN

- **Nutrient Film Technique**
- tip of the roots in water
- rootzone surrounded with oxygen

- great root growth, great oxygen levels
- root rot, no buffer on fail, difficult for larger plants, separate biofilter for aquaponics

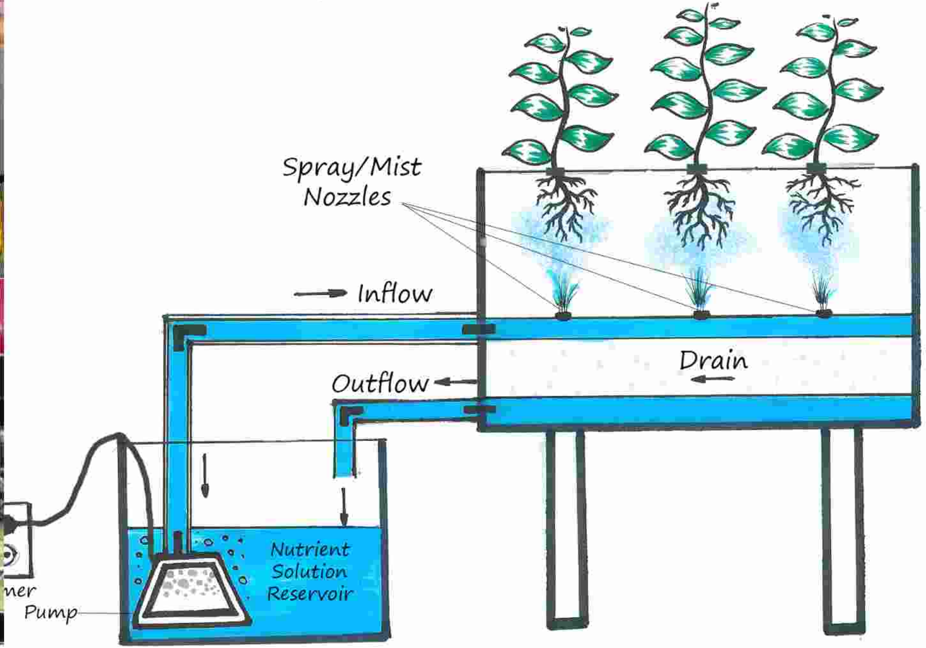




SYSTEM DESIGN NFT

- **Aeroponics**
- rootzone sprayed with water mist

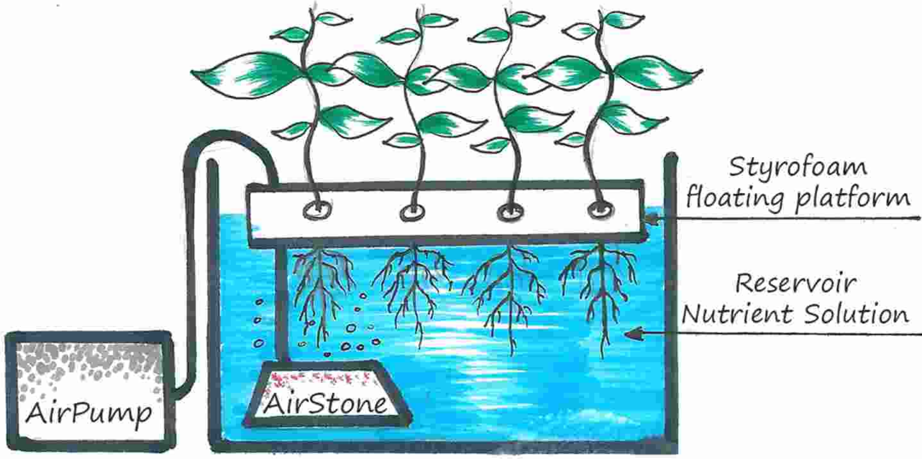
- no aeration needed for water reservoir, uses complete rootzone for nutrient take up, very fine mist helps with nutrient uptake
- nozzles clog really fast, no buffer on fail, difficult for larger plants, separate biofilter for aquaponics



SYSTEM DESIGN AEROPONIC

- **Deep Water Culture**
- roots completely saturated in oxygenated water

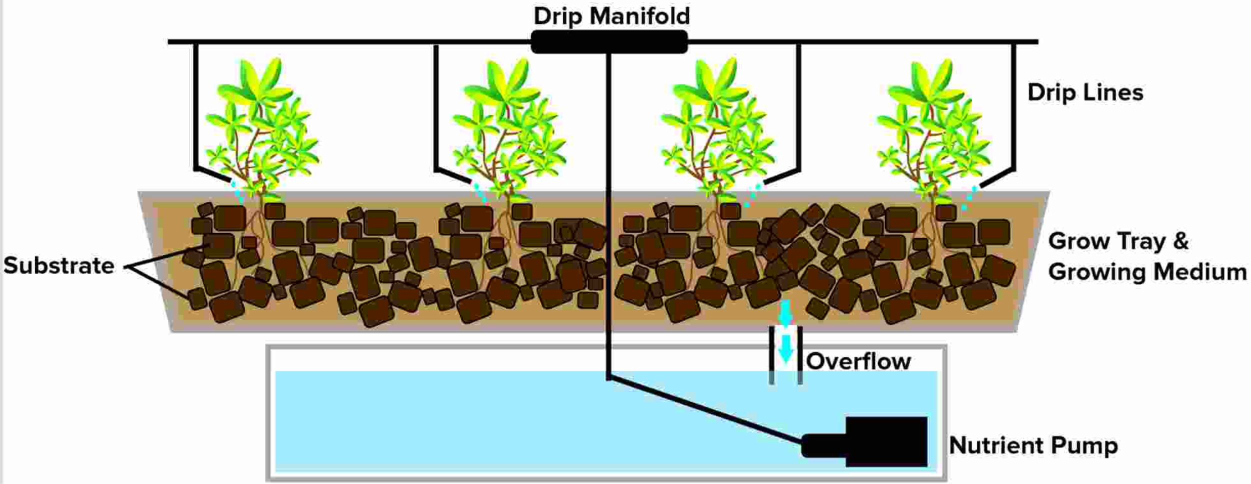
- very popular - simple system setup, controllable rootzone oxygen level, buffer on fail
- root rot, diseases / pests for aquaponic you need a separate reservoir for aquatic animals, separate biofilter for aquaponics



SYSTEM DESIGN DWC

- **Drip system**
- more or less like traditional agriculture, but without soil

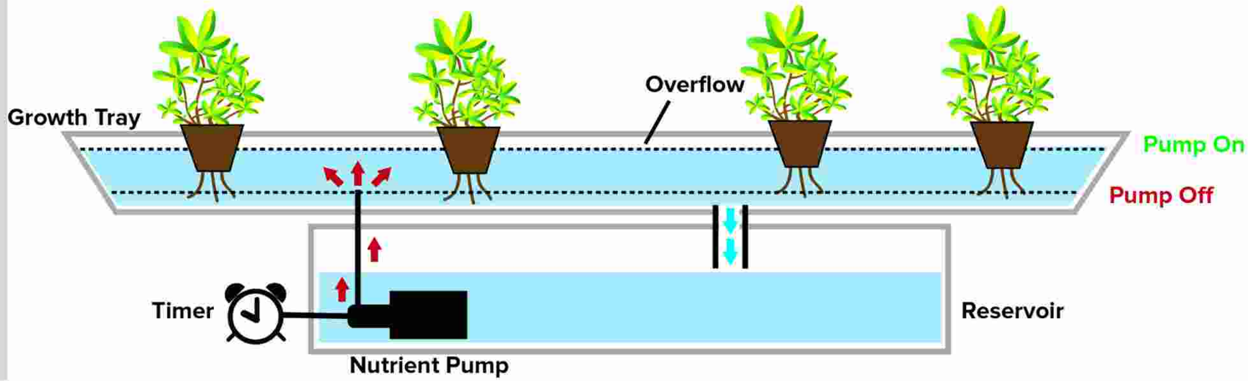
- media acts as a buffer in case of fail, can supply each plant with water from a different reservoir, for aquaponics growbed can be used as biofilter
- not enough throughput for aquaponic - filter function



SYSTEM DESIGN DRIP

- **Flood and Drain** or Ebb and Flow
- uses grow media that regularly gets flooded with water

- easy to build, aquatic animals directly live in the water reservoir, media is a very good buffer on system fails, good with plants of all sizes, grow bed is biofilter at the same time, you can use red worms to help with filtration
- maintenance a little more difficult, not feasible on an industrial scale



SYSTEM DESIGN FLOOD AND DRAIN

- Size matters, smaller systems are harder to control, higher spikes
- ratios of water volume to growbed volume (1:1 - 2:1)
- growbed depth (15 - 35 cm)
- stocking density (0.5 kg per 20-26 liters)
- clogging, reverse flow
- sump tank, don’t let your fish dry out...

FLOOD AND DRAIN DESIGN CONSIDERATIONS

- played around quite a bit and tested different system setups
- flood and drain was the best, usability wise

- arduino, relayboard, raspberry pi

HUMBLE BEGINNINGS

Meet the
Robotic Aquaponic Ecosystem

automated water cycle

light intensity sensor,
temperature and humidity sensor,
(water level sensor)

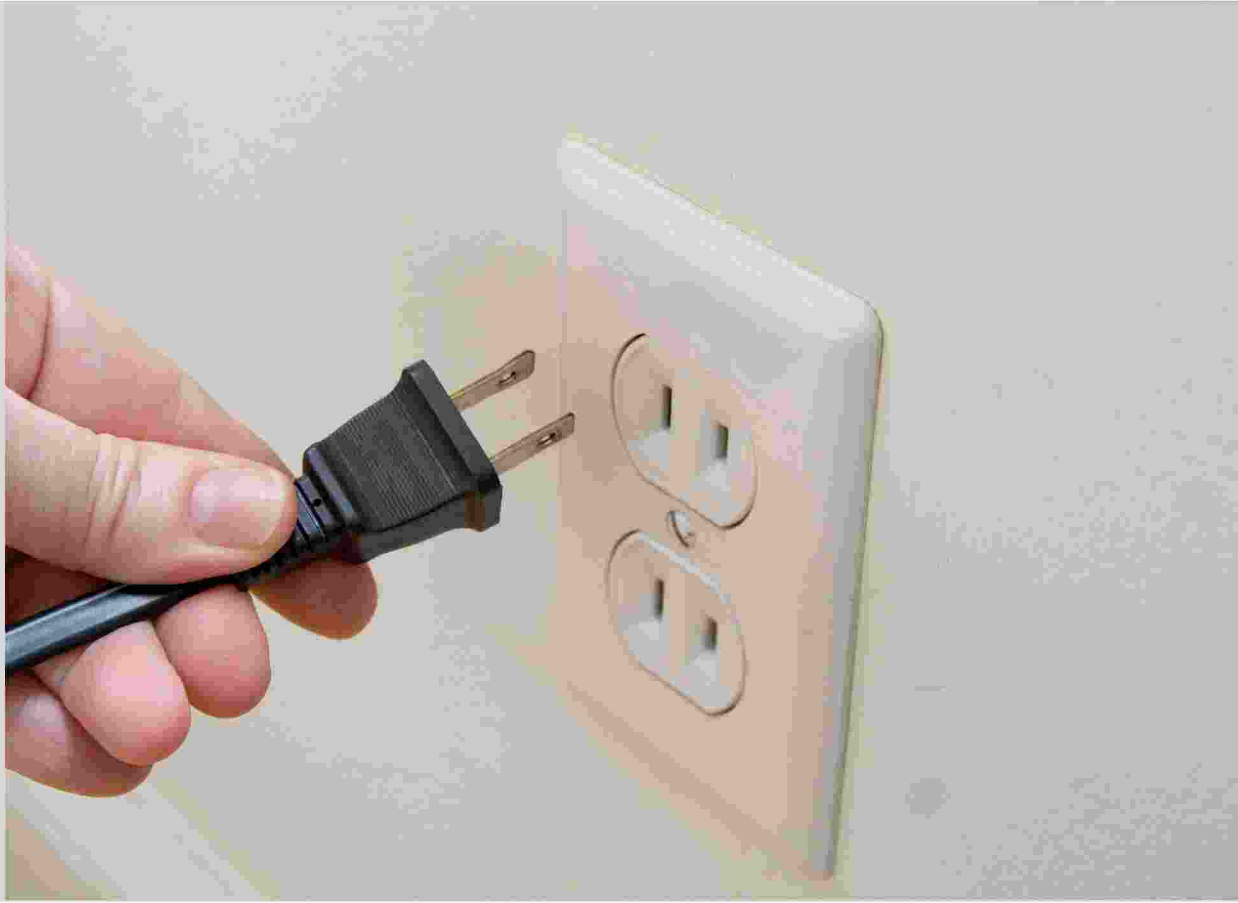
Arduino at heart
USB serial interface

- **please gather parts**

- 2x useful boxes with lids, 1x small box with lid
- 1m water hose, 2x hose connectors
- water pump
- relay board
- micro controller
- temperature sensor, resistor
- light sensor
- zipties
- knife

- let's start working on the case

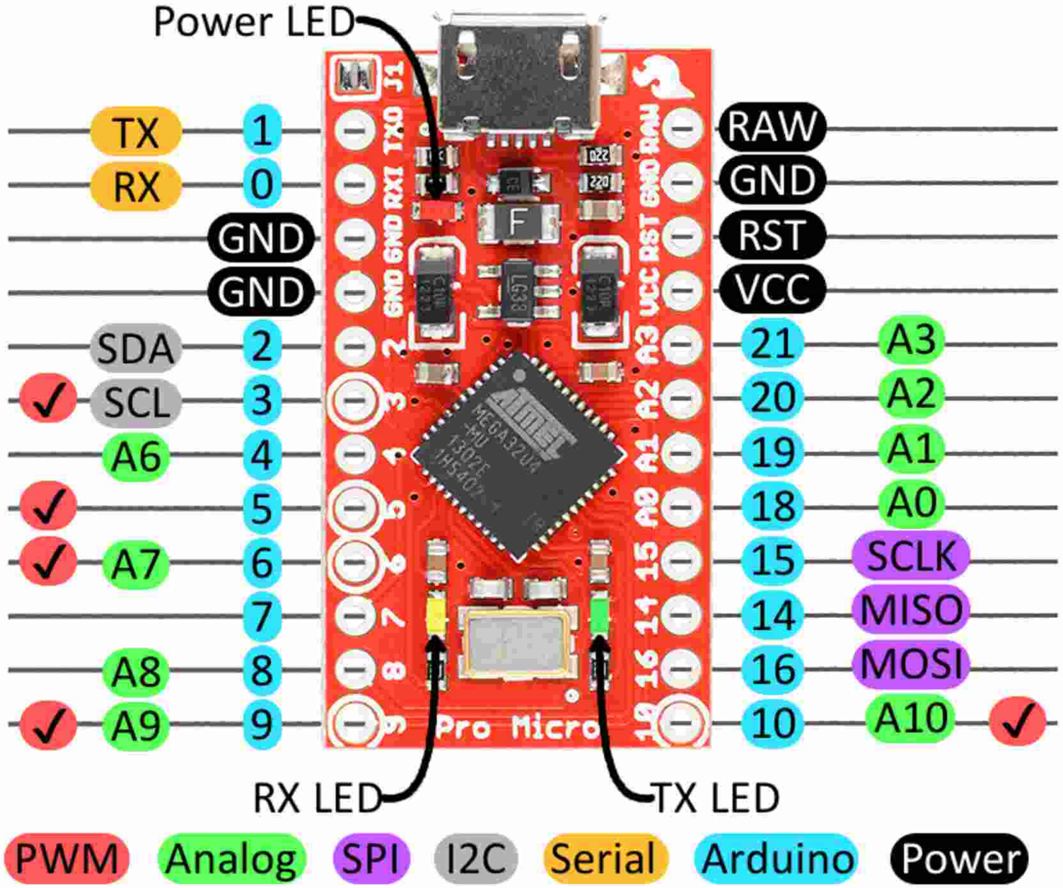
CHAPTER 1 - GET THE LOOT



- nice, plug it into the wall and we're good to go
- not quite, pump is always on, should save some energy, noisy at night, oxygen supply for roots
- should make it smart, so that it runs in intervals and doesn't turn on at night
- how? microcontroller!

HARDWARE PUMP

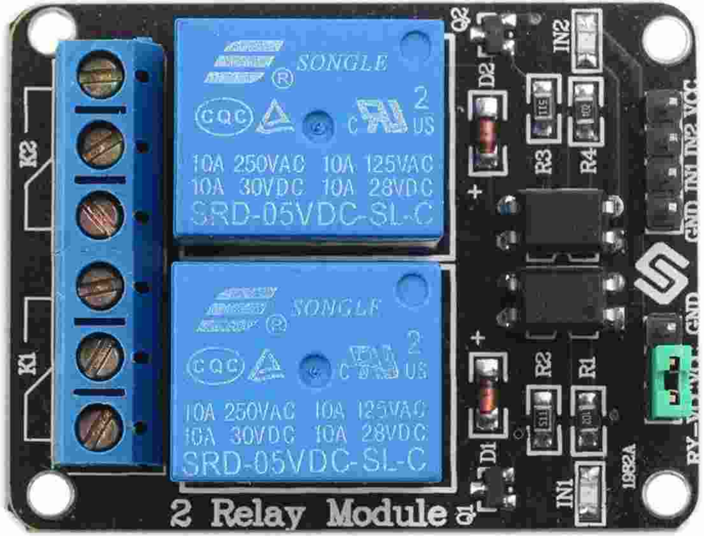
- this is an arduino pro mini clone
- 8bit 32Kbytes avr 32u4 microcontroller with a risk architecture
- code will be in C/C++
- arduino wrapper called wiring around C++ made these contoller popular
- switching values of ports results in different actions on the pins
- output / input
- controller is running on 5V DC usb power and features a usb Serial to communicate with a computer
- but how do we switch a 220V AC pump with a 5V DC controller?

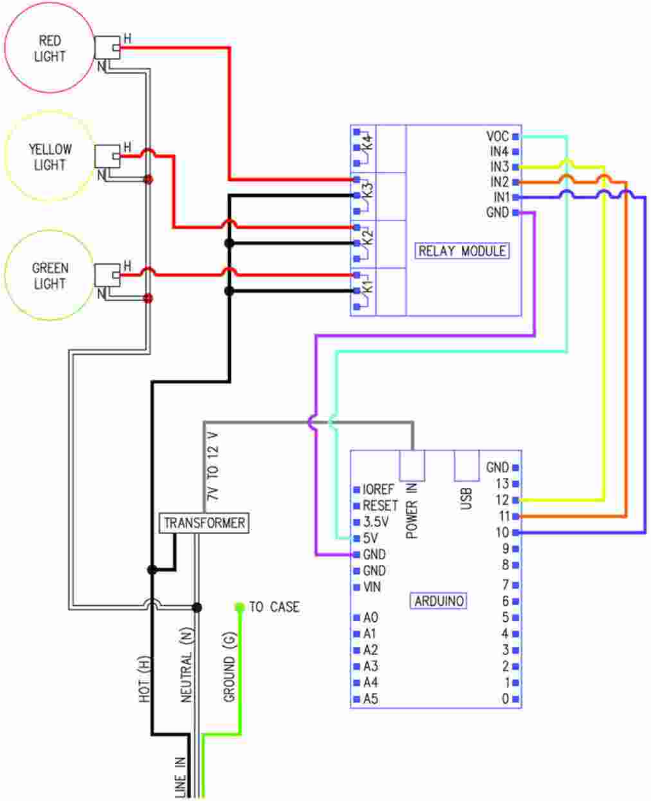


HARDWARE MICROCONTROLLER

- switches circuits through el magnets
- use 5V DC sig from MC to close 220V AC circuit
- rating, signal U/I, switching U/I

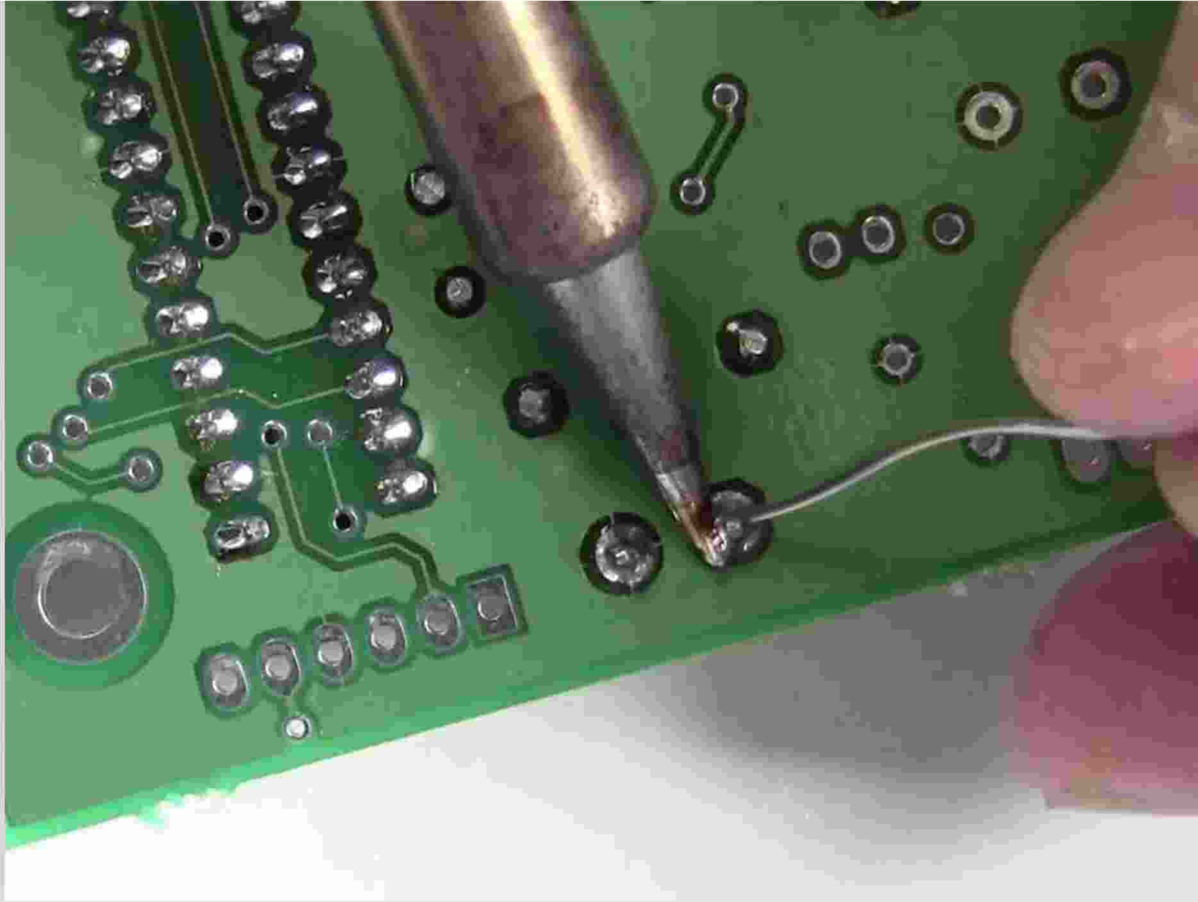
- 2 channels, we'll only use one for the pump
- you can add an additional hardware and control it with the mc (aerator, heater, fans, lights, etc



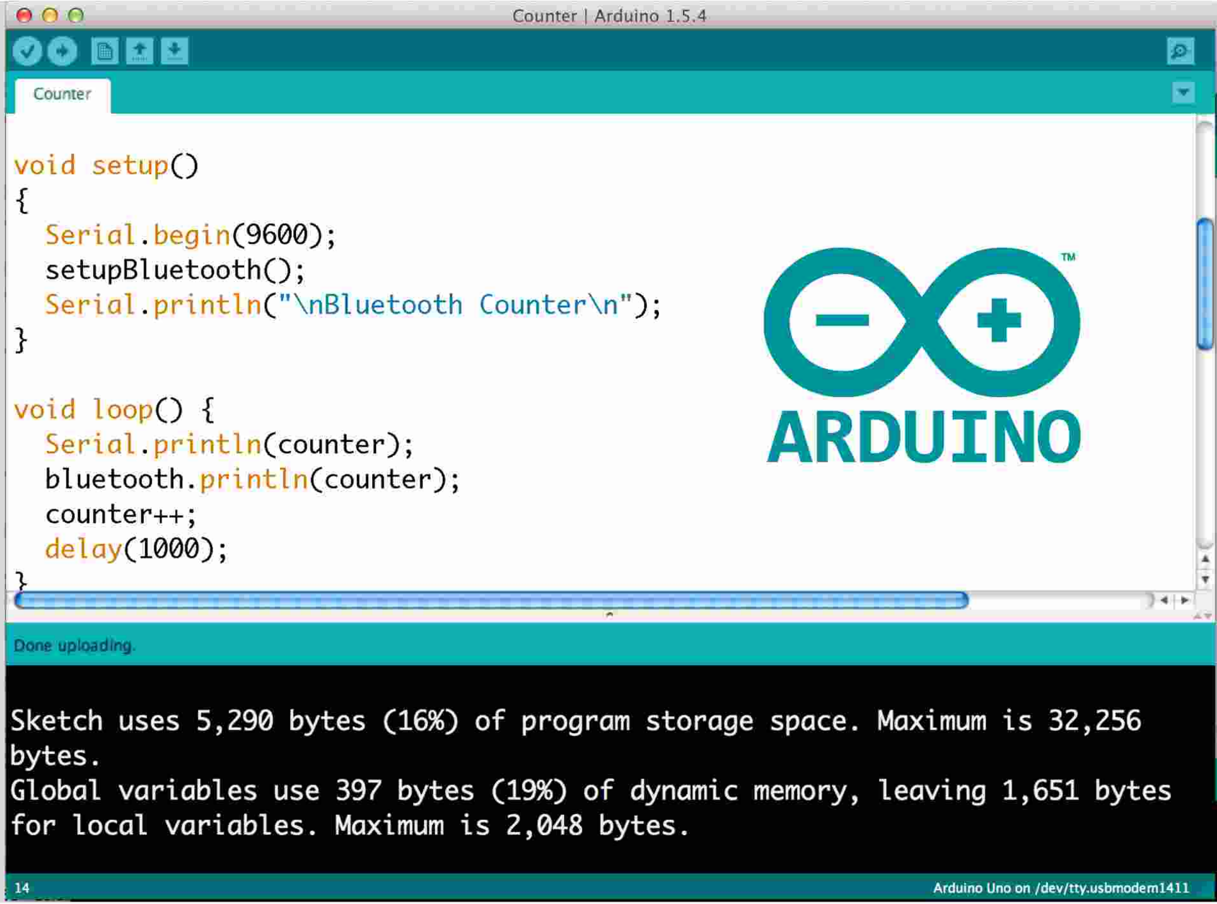


HARDWARE RELAY BOARD

- hook up mc with relay board
- hook up pump with relay board



CHAPTER 2 - CONNECTING BRAIN AND MUSCLES

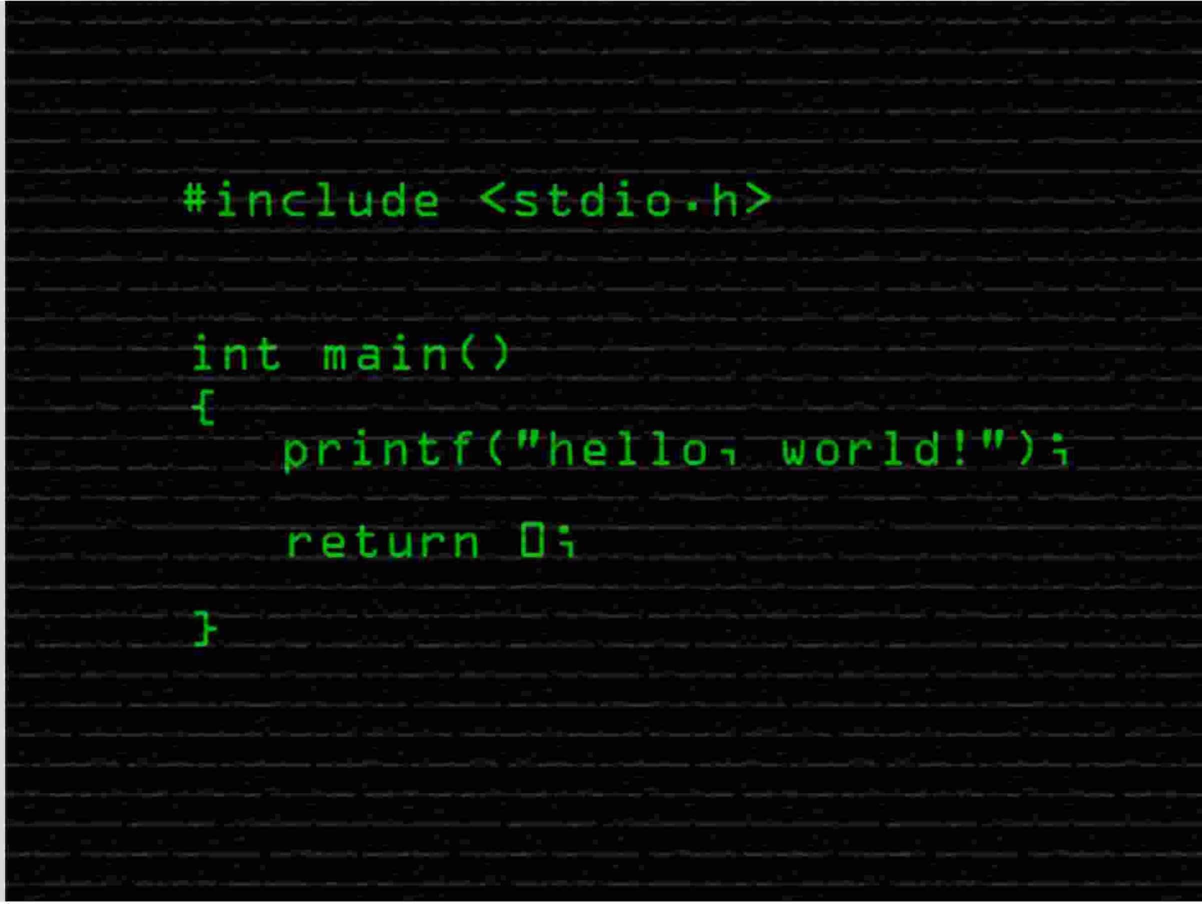


- arduino, popular stuff, makes using mcs easy, wrapper for c++ to handle port manipulation and higher-level stuff the easy way
- basics setup () and loop ()
- USB flash + serial

SOFTWARE ARDUINO

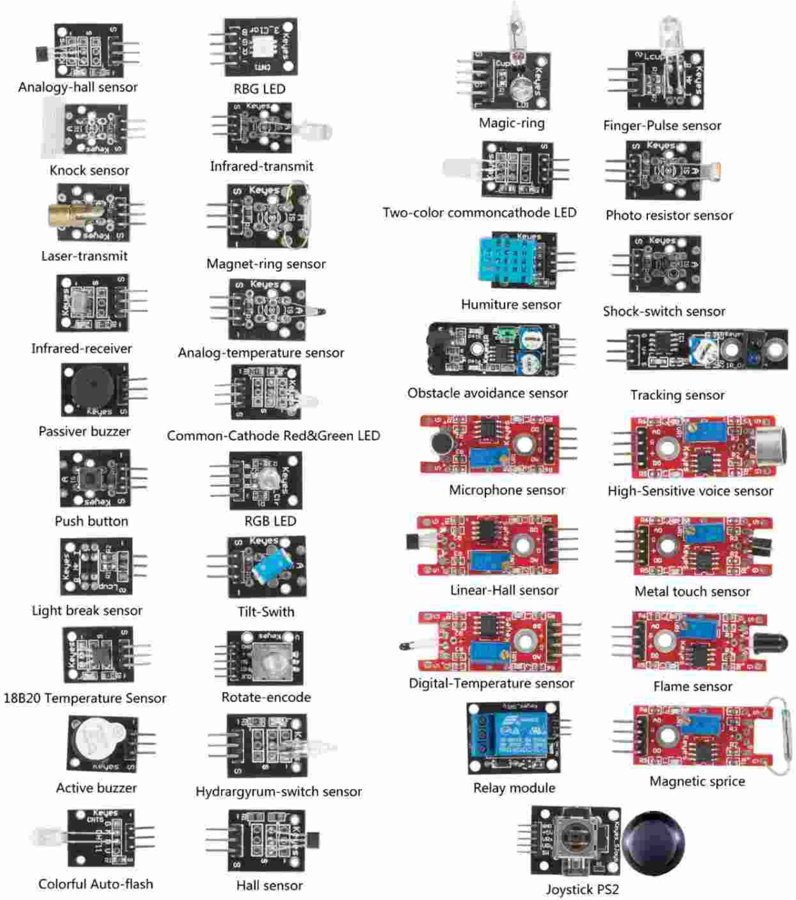
- please download and install Arduino IDE
- set up and switch output pins of the mc, toggle channel on the relay board based on a delay
- code hello world on mc, give it out over serial

- do stuff on serial receive



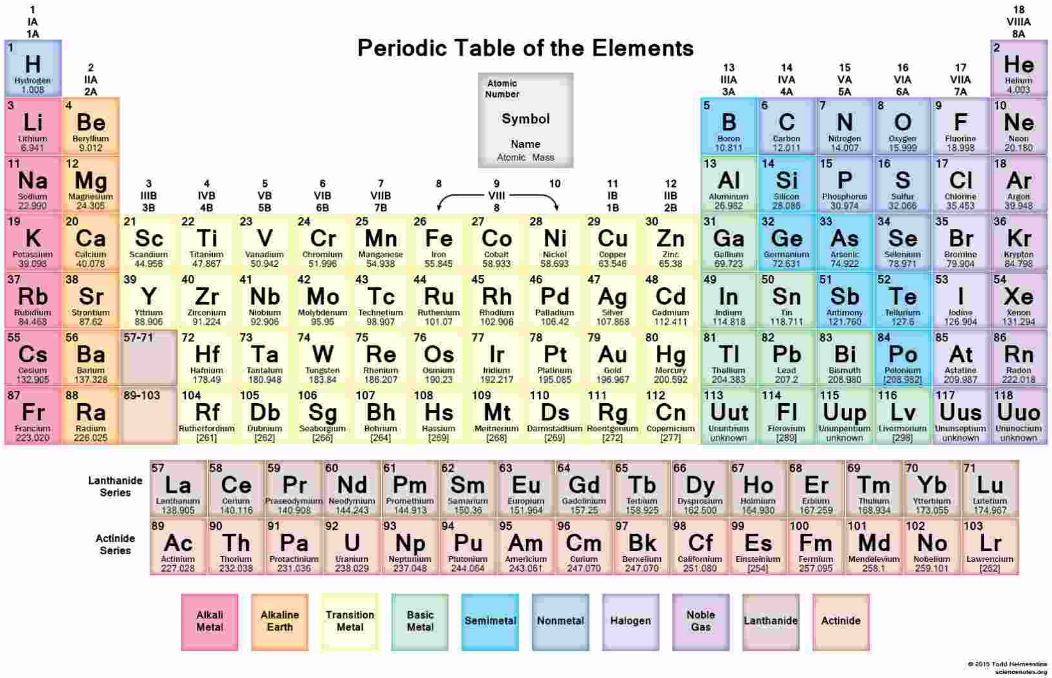
CHAPTER 3 - HELLO WORLD

- low to high cost
- sensors for everything
- they all use one of the following protocolls (analog, spi, I2C, serial, onewire)
- our mc can handle them all
- for digital communication we'll use libraries, makes life easy



HARDWARE SENSORS

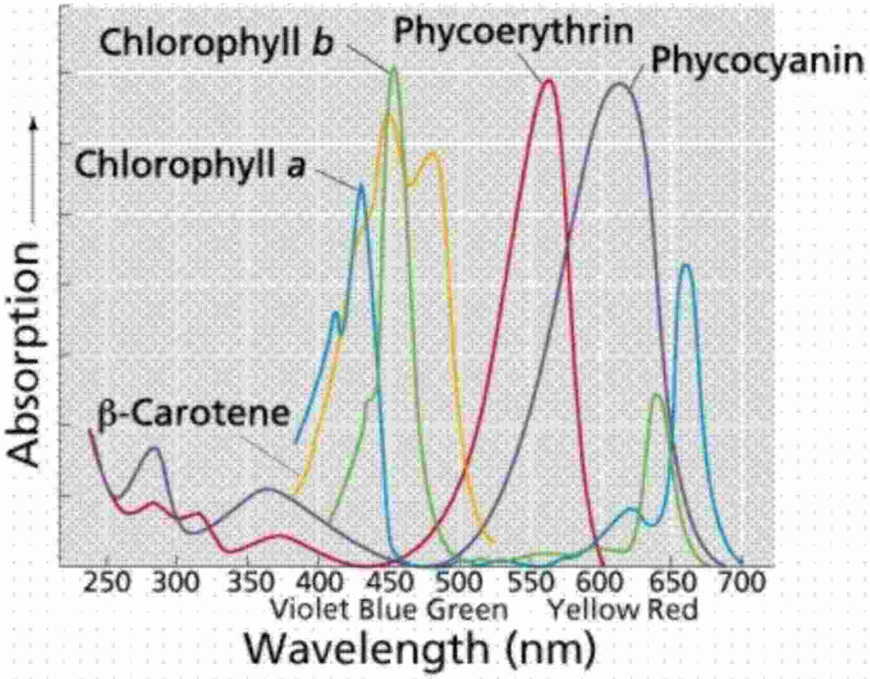
- what do we want to measure in an aquaponic system
- parameters often linked to each other
- ie light measured in ppm, max usable ppm of a plant depends on temperature
- finding these connections and thus finding the right balance of parameters is key for efficient systems
- so we want to know it all (still ongoing experiment on this, use computing to solve)
- PH, EC, CH, DO, temp, humid, CO2, light spectrum, light intensity, mechanical stress, oxygen in the rootzone



AQUAPONIC PARAMETERS

PLANTS LOVE PHOTONS

- most important factor for plant growth
- spectrum / intensity / duration / interval
- PAR - photosynthetic active radiation
- ppm in microeinstein per scm, not LUX or LUMEN (human visible spectrum)
- how long is the light on
- how long is the light off
- too much light, not enough light
- compare different light sources, led, dampflamplen, sparlampen, halogen, etc



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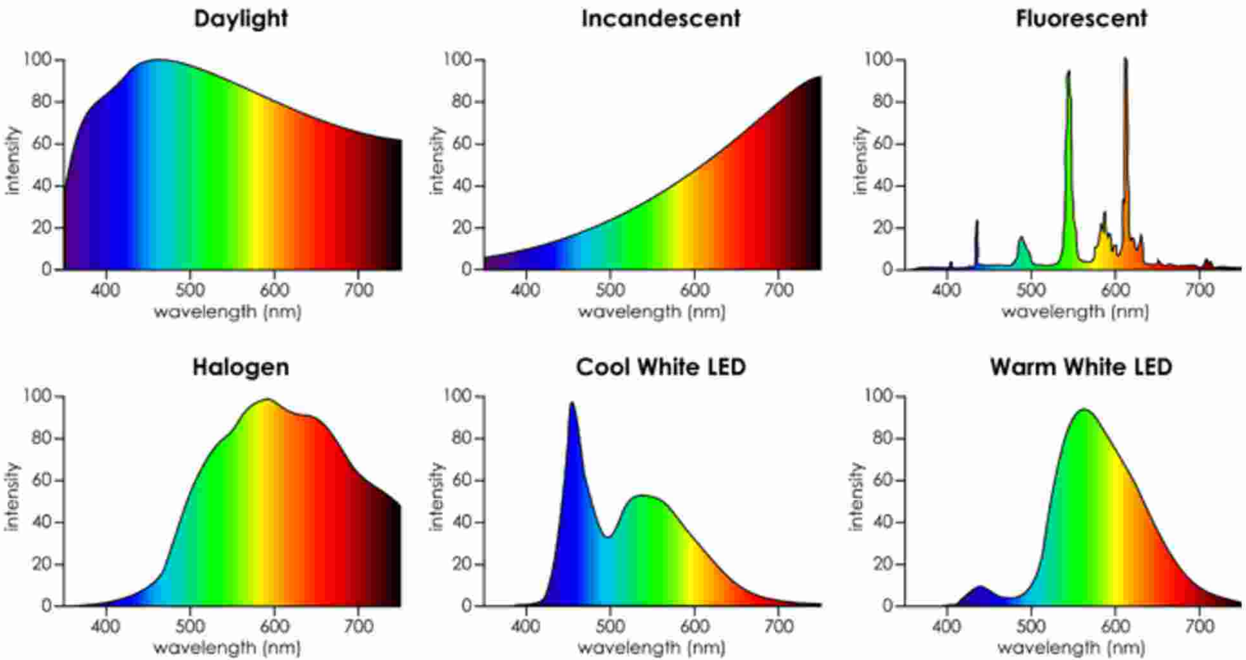
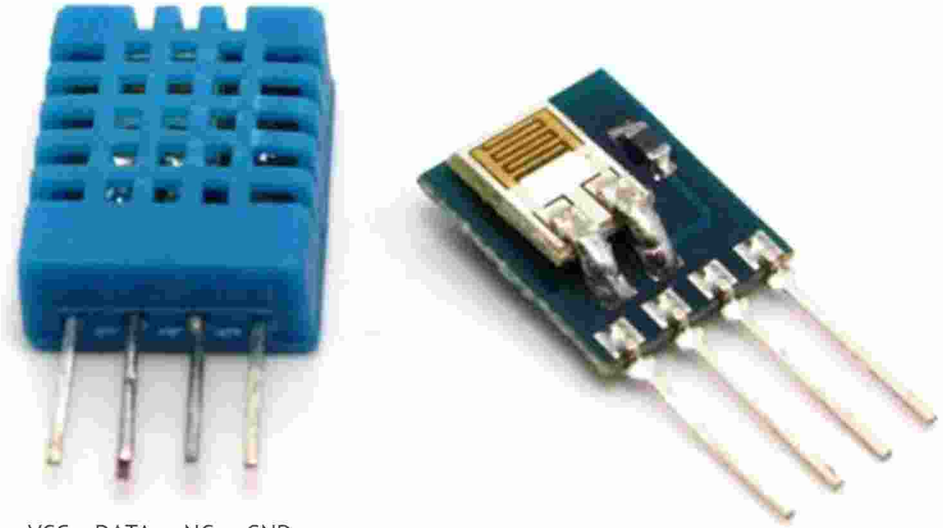


PLANTS LOVE PHOTONS

- wire up photodiode
- put sensor in place
- read out sensor data and display it via serial

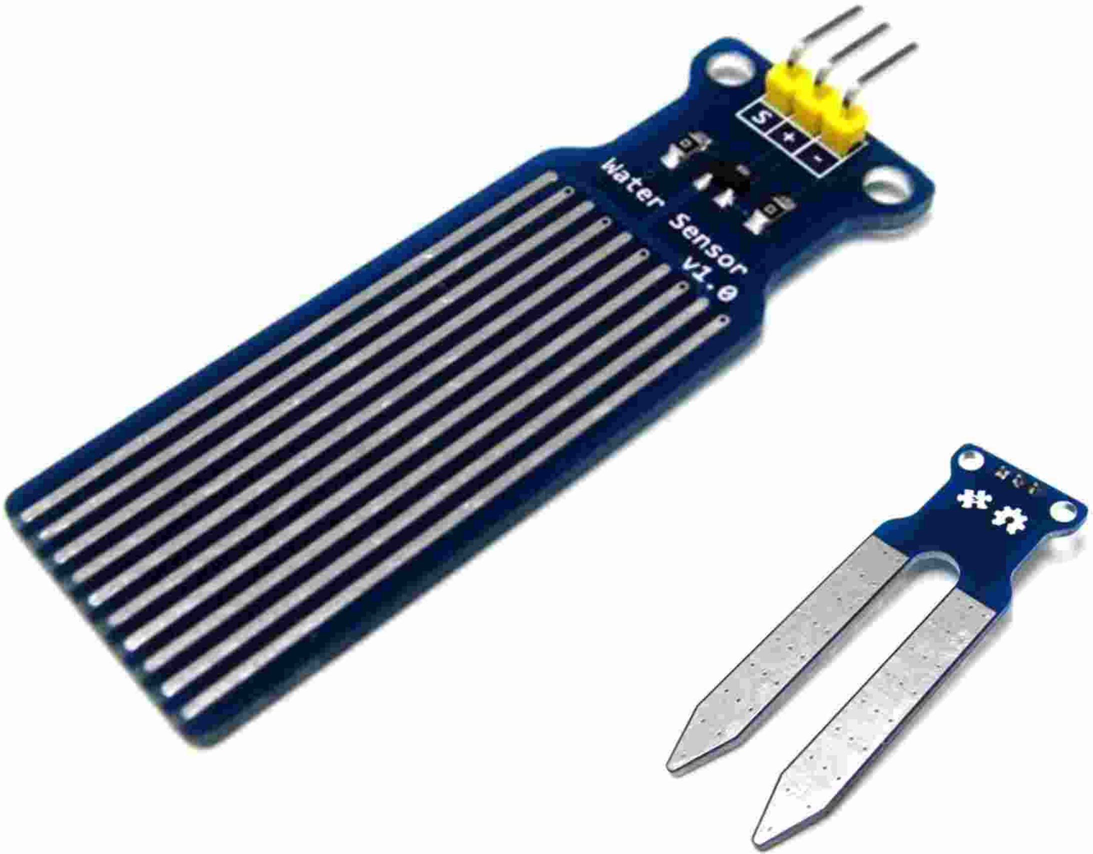
CHAPTER 4 - THE SUN IS SHINING

- wire up DHT11 sensor (10k pullup btw. DATA and VCC
- put sensor in place
- read out sensor data and display it via serial



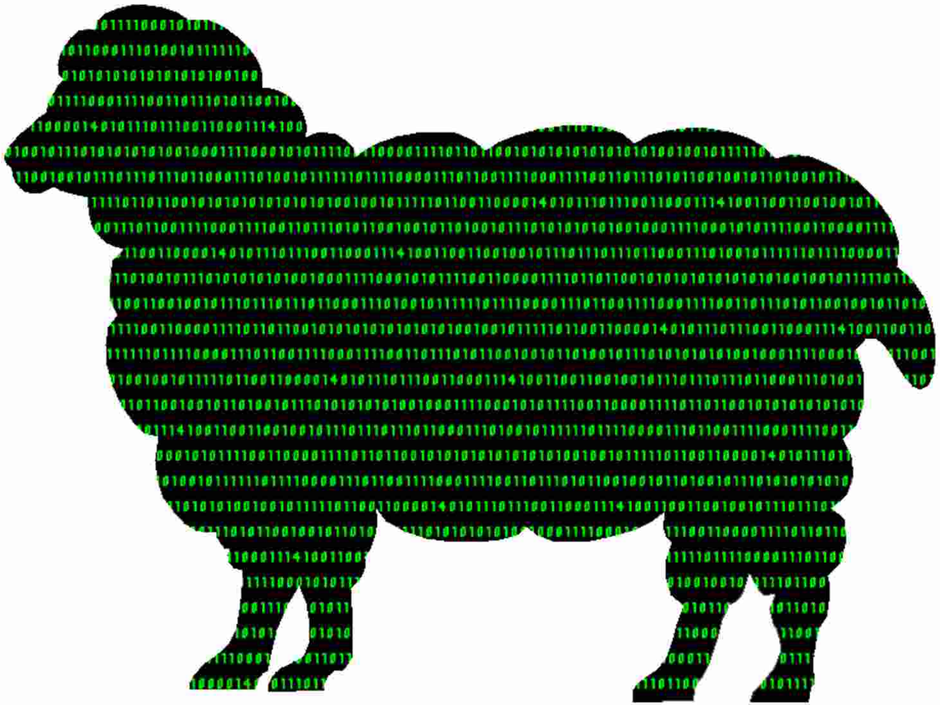
CHAPTER 5 - AS COLD AS ICE

- build basic water level sensor
- put sensor in place
- read out sensor data and display it via serial
- should be stainless steel, no corrosion, no toxic substances in water



CHAPTER 6 - DIY WATER LEVEL SENSOR

- bringing it all together
- controlling actuators based on sensory input
- lightsensor and or watersensor -> pump
- temp / humid sensor -> imaginary heater or fan



Do androids dream of electric sheep?

CHAPTER 7 - LET YOUR ROBOT DREAM

- ziptie fun, lots and lots of zipties...

CHAPTER 8 - FINISHING UP

- find a place for your little robot, connect relay board and mc to power
- fill it with water, rainwater is best, or tap water but let it rest for 2 days
- put in some fish, small fish are better, don’t use goldfish, get correct stocking density (guppy 20 - 50 pcs)
- fill growbed with grow media

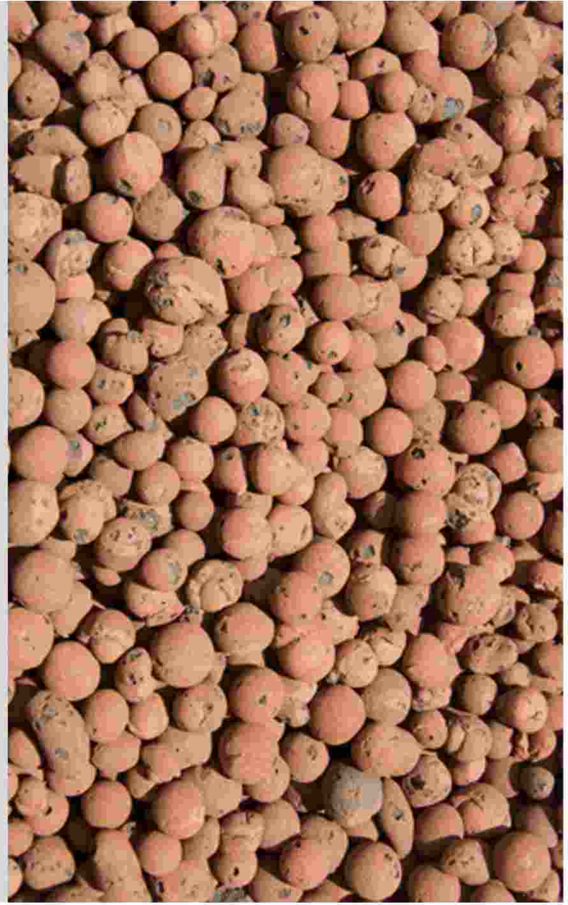
WHAT’S NEXT

- inert / ph / toxins
- large surface area (BSA - biological surface area)
- porous material (organisms need to cling on to)
- capillarity vs grain size (oxygen in rootzone)
- humidity buffer (organisms don't dry out at once)

- cocopeat, perlite, volcanic rocks, kies, hydroton (seramis)

- System cycling up to 8 weeks
- use low stocking density first, increase over time
- use less fish feed in the first few weeks
- grow fast growing crops first, cress, arugula, etc

- you know your system has been cycled well if nitrite drops and nitrate increases

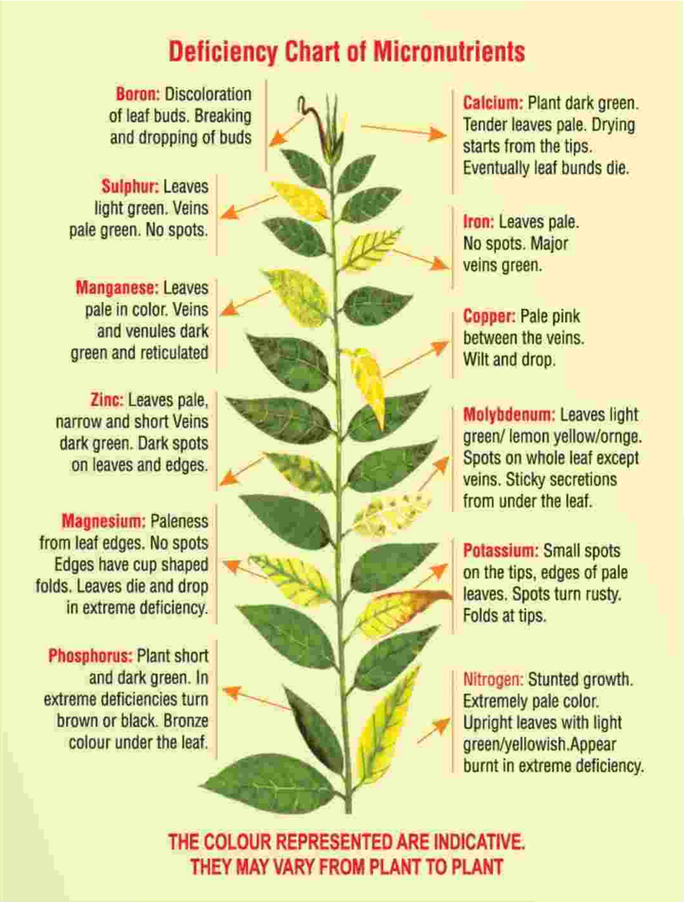


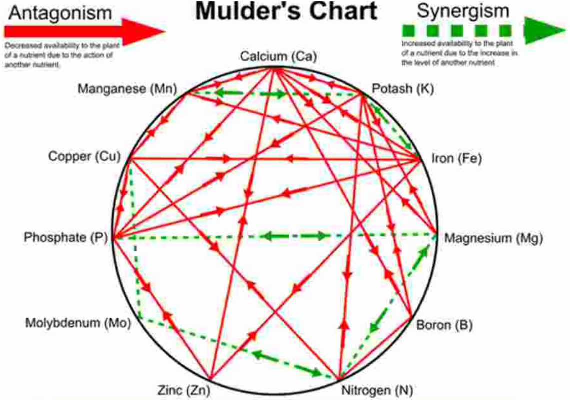
CHOOSING THE RIGHT GROW MEDIA

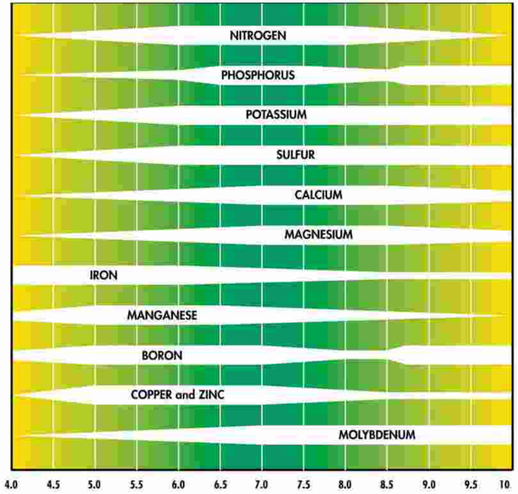
RECOGNIZING DEFICIENCIES

- micro / macro nutrients
- every plant needs a different mix
- if something is missing, plants will tell you

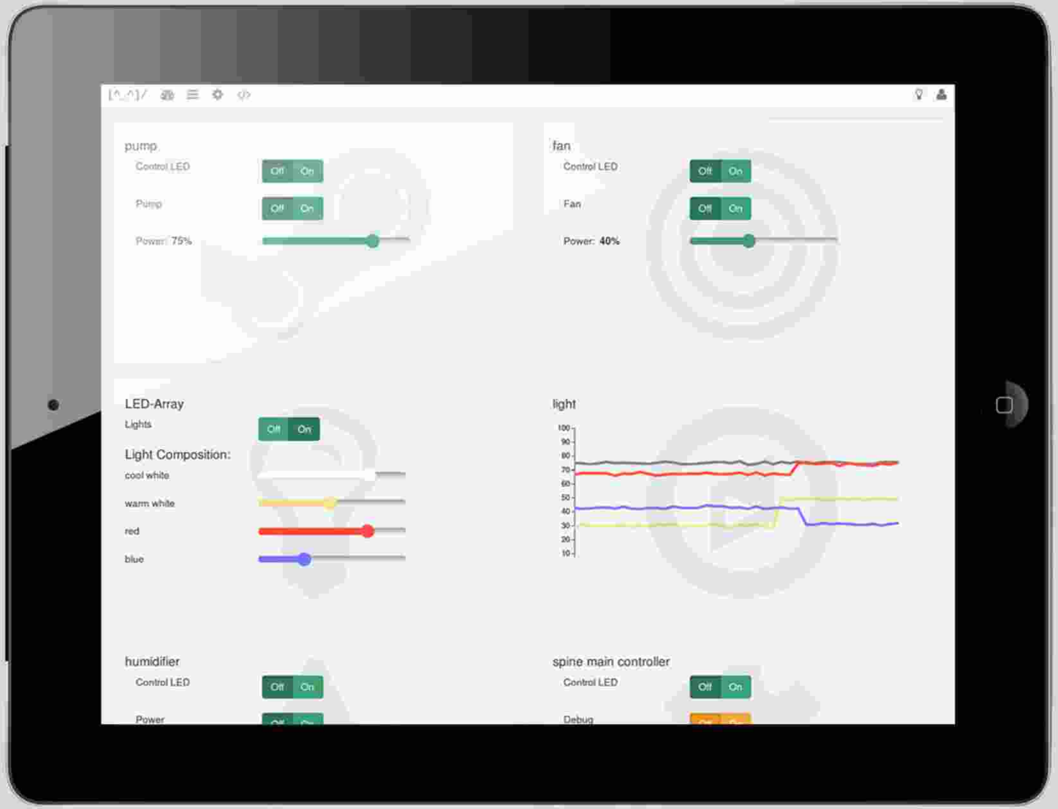
- recognizing deficiencies with a chart
- mobile / immobile nutes
- what to do when you know what's missing? can the sys be optimized? if not, add additives - just ask the internet







- possible system upgrades
- heater, fan, humidifier, IR filter, artificial light, PH sensor, speakers so you can play some metal for your plants
- interface, raspberry pi
- mail, sms etc alerts
- check out code on our github, see some prototypes
- to much of a hustle? wait for our diy kit (plug n play, extendible, with an epic interface and community that helps you growing)



EXPAND YOUR SYSTEM

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QUESTIONS, GROW REPORTS & SAMPLES