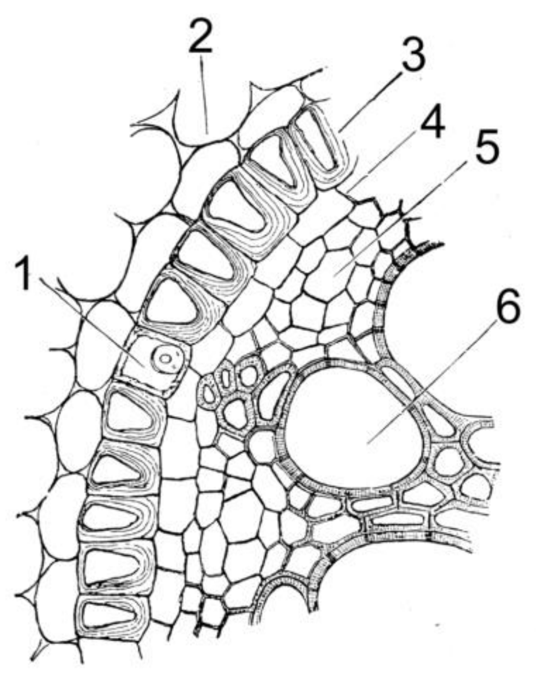
Task 2 The Secret of Roots

Introduction:
In this project, we, the Tertia 2 from the Freies Gymnasium Bern, in the context oft the „simply science challenge" have researched and experimented with roots. We wondered how roots react to different soils. This meant we had for example to change the quantity of fertilizer which we added to the soil to look how the roots react to this special external influences.

Part 1: Background information

1. Passage cells [1]: Control the intake of the root, by only selectively letting certain solutes by.
2. Parenchyma cells [2]: Strengthens the root from the outside.
3. Endodermis [1]: The boundary between the cortex and the stele.
4. Pericycle [3]: A cylinder, which lies just inside the endodermis, and is capable of producing branch roots.
5. Phloem [4]: It carries the nutrients through the root to the rest of the plant.
6. Xylem [5]: Next to Phloem, additional transport tissue. Example: Wood. Mainly transports water.

Xylem und Phloem = Transport tissue



A) Roots in science. Why may they be of interest in respect of…?
Physiology: The Article listed below explains the changes, that the roots of the Arabidopsis thaliana experiences, when exposed to elevated levels of Carbon dioxide. Within some time we might be able to identify, what happens on a genetic level, once these changes occur and possibly last for generations as mutations.
Biochemistry: Roots have the special ability, to synthesize a vast amount of different metabolites. It could be possible, to try and find out how exactly the process works and then even possibly using said ability for the benefit of humans, apart from using the roots directly as medicine as is described in the article.
Economy: Ass seen in the article, roots respond in a positive way to soil nitrogen. That fact may be used to positively affect the food industry or any other work branch related to plants. If we know how to influence roots, we can easily influence the rest of the plant, without manipulating its genes.

B) How is dew formation (guttation) connected to activities in roots?
The formation of dew affects the roots in such a way, that if the dew is to be made use of, the roots must be relatively shallow, because the moisture of the dew only penetrates a thin layer of soil.

Reference List:

(1) http://en.wikipedia.org/wiki/Endodermis, 08.05.15
(2) http://en.wikipedia.org/wiki/Parenchyma , 08.05.15
(3) http://en.wikipedia.org/wiki/Pericycle , 08.05.15
(4) http://en.wikipedia.org/wiki/Phloem, 08.05.15
(5) http://en.wikipedia.org/wiki/Xylem, 08.05.15

How dew guttation is connected to activities in roots.

http://eps.berkeley.edu/people/lunaleopold/(036)%20Dew%20as%20a%20Source%20of%20Plant%20Moisture.pdf

Roots in science. Why may they be of interest in respect of…?
Physiology: http://jxb.oxfordjournals.org/content/49/320/593.short
Biochemistry: http://lamar.colostate.edu/~jvivanco/papers/Trends%20plant%20sci/Flores1999.pdf
Economy: http://aob.oxfordjournals.org/content/66/1/91.short

Part 3: Design of Our Project

Aspect 1

After some brainstorming we had our specific question: "How do the roots of different plants grow in different environments?"

After some discussion we defined the controlled variables:

- Soil, is gelatine → So we could see the roots.
- Temperature → Because when it is to cold or hot the plants don`t grow anymore.
- Environmental conditions → same atmospheric pressure (difficult to change), humidity and watering
- The independent variables:
- Different concentrations of a nutrient/ substance → it`s very simple to manipulate this variable
- Different positions of the nutrient → so we could see, if the roots decided to favour a specific nutrient/concentration
- Different plants → to observe, if the roots of different plants decide to favour the same nutrient/concentration

Aspect 2

Our first apparent problem was, that we could not look at roots without damaging them. We had to find a substance through which we could see through and plants could properly grow through.
Our solution was a translucent gelatine. We filled the different gelatine types in small plastic boxes. The different concentrations were pure gelatine, 0.5%, 1% and 2.5% fertilizer and as well 1% sodium chloride.
We put the seeds on the surface. In this way we allowed the roots to grow through all the vertical and horizontal layers the same way.

Perperation: We cooked gelatin with water and gave different minerals at different concentrations to the mix:

- 0.5 % Fertilizer
- 1% Fertilizer
- 2.5% Fertilizer
- 1% Sodium Nitrate
- Pure gelatin

After the gelatin hardened we cut the mixes into slices and layed them onto or next to each other in different combinations. Then we planted radish- and cress seeds over following combinations:

- Single Layer:
  - 0.5 % fertilizer
  - 1% fertilizer
  - 2.5% fertilizer
  - 1% sodium nitrate
  - pure gelatine
- Layers from top to bottom:
  - **Composite 1:** 0%, 0.5%, 1%, 2.5% fertilizer
  - **Composite 2:** Only gelatine, sodium nitrate
  - **Composite 3:** 2.5%, 0.5% fertilizer
- Layers from right to left:
  - **Composite 4:** 0.5%, 1%, 2.5% fertilizer
  - **Composite 5:** Only gelatine, 1% fertilizer, sodium nitrate

Aspect 3

Method of evaluation:
We measured the length of the roots and in which layer they were in at the time. While measuring, our goal was to highlight the differences between cress and radishes.

Part 4-5: Data Collection and Conclusion

Singles:
The singles had problems with the water supply and are therefore not very meaningful.

Composite 1: (plain, 0.5%, 1%, 2.5%) fertilizer
From the results of this trial we can interpret that most of the cress plants (ca.90%) tried to grow as deeply as possible, presumably to access the higher fertilizer percentage layers. The fact that roughly 10% grew around the gelatine can be seen, as a search for the ideal nutrient concentration. However one could also assume that the plants where just taking the path of least resistance.
By interpreting the Radish results we can conclude that Radish either needs a lower concentration of fertilizer or that it has weaker roots that grow at a slower pace. The slower pace of growth would be backed by the fact that only 50% grew sizable roots. But we do know that Radishes do need fertilizer (all that grew sizable roots penetrated the gelatine).

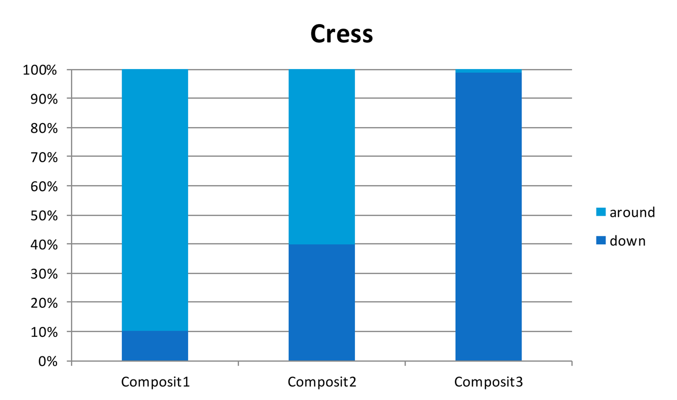
Composite 2: (top; plain, bottom; sodium nitrate)
In this situation a very large percentage of the roots went around the gelatine (ca. 60%) compared to the previous situation (only 10%), we could interpret this in two ways: We could assume that this was just a coincidence, however one could also think that this was the choice of the plants, as growing through nothing is considerably easier then growing through gelatine. This would also be of benefit when considering that the nutrients where on the lower layer.
Now one might ask why the radishes didn't do the same thing, our answers to this that the way that the Radishes outgrow their competitors. Our hypothesis is that radish has strong roots that grow directly down even through hard ground, in this way they will grow to the nutrients that can't be reached by the other plants.

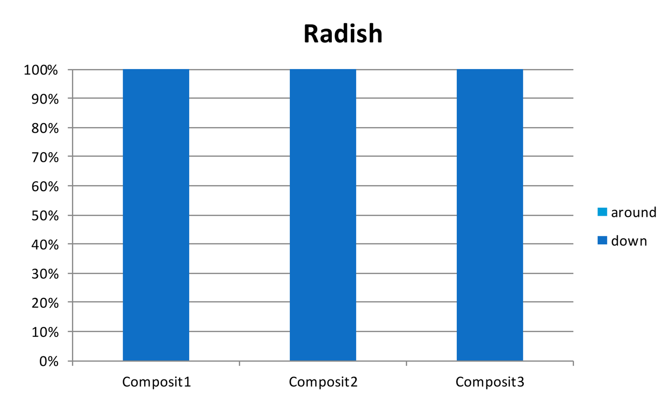
Composite 3: (top; thin 2.5, bottom; thick 0.5 fertilizer)
In this case none of the roots grew around the fertilizer and all of the roots grew directly into the top layer which had the highest amount of fertilizer. This makes sense as growing deeper would only have a negative impact.

Composite 4: (right; 0.5 %, middle; 1%, left; 2.5%) fertilizer
We can see that in all different fertilizer concentrations the cress grew. We can also see that it grew differently depending on the area (right, middle and left). We can also see that the cress likes 1% fertilizer the most (Most of the plants that grew to a side grew to the middle where 1% fertilizer was, also this was the area where the most cress sprouted).The Radish was similar. The bigger the concentration the better it grew. However the radish never grew into another area instead it always grew straight down. The Radish just like cress grew best in 1% fertilizer.

Composite 5: (right; plain, middle; fertilizer (1%), left; sodium nitrate)
In this case we can see that for cress sodium nitrate was the area most of the cress grew to. The cress in the middle moved to the other sides (left and right) and the cress on the right generally stayed on the right. The radish on the other hand grew the best in 1% followed by sodium nitrate, plain did the worst. The cress in this case contradicts the radish and the previous results.

Conclusion of previous conclusions:
As a total we can conclude several things. The first being that the plants will generally grow towards the most ideal concentration of nutrients, this can be seen particularly well when comparing composite 1 to composite 2. Another thing we can conclude is that the two plants have two different ways of finding nutrients: The cress has long roots which grow into several directions taking the path of least resistance and growing to the area of most ideal concentration, the roots which are in an area without minerals then regress leaving only the roots near minerals (Graph 1). The radish grows directly down with its short yet powerful roots (in this way they can grow deeper than the competitor plants (Graph 2)). Another thing is the importance of the different minerals and mineral sources, we can see that 1% fertilizer is the most ideal for the plants, as the fertilizer concentration increases it gets progressively less ideal to the plants (we think that this is because it starts damaging the plants). Sodium nitrate was more ideal than plain and less ideal than 1% fertilizer.





Improvements:
There is a multitude of different ways to improve our work. For example: if we would make more experiments, there would be less room for mistakes. If the plants would have had more free room to grow, our data might be closer to real life examples. Speaking of real life, the outside factors also play a great role. For example in an optimal environment (steady temperatures, optimal humidity, no direct sunlight (the gelatine would melt otherwise)). The data would be more objective, if there would be a higher diversity of plants/roots and said plants could be planted in a more or less sterile environment. Another helping factor is, more time. The more time given, the more experiments could have been made over a longer time period. All in all, there is always lots of room for improvements.