<u>Project Notes</u> <u>:</u>

<u>Project Title:</u>
<u>Name: Jessica Froment</u>

<u>Note Well:</u> There are NO SHORT-cuts to reading journal articles and taking notes from them. Comprehension is paramount. You will most likely need to read it several times, so set aside enough time in your schedule.

Knowledge Gaps :

This list provides a brief overview of the major knowledge gaps for this project, how they were resolved and where to find the information.

Knowledge Gap	Resolved By	Information is located	Date resolved
How do tree networks send info	You tube video	https://www.youtube.com/watch?v=_tjt8WT5mRs	9/1/24
Difference between arbuscular MN and common MN	Journal Article	https://nph.onlinelibrary.wiley.com/doi/10.1111/nph.15775	10/1

Literature Search Parameters:

These searches were performed between (08/14/2024) and 09/27/2024.
List of keywords and databases used during this project.

Database/search engine	Keywords	Summary of search
Brain cancer	Mylin sheaths Brain tumors	Brain cancer is most common within Mylin sheaths as neurons replicate slowly
Mycorrhizal fungi	Tree networks Fungi Comon Mycorrhizal networks Signaling molecules	Plants are able to send signaling molecules through Mycorrhizal fungi. This is pretty understudied and would be a good area of research d

Tags:

Tag Name	
#RASprotien #microbiology #biology #cancer #probability #forcasting #weather # chemistry #globalwarming #environment #geneediting #mycorrhizal networks #mycorrhizal networks #Carbon #CMNmodel #MN #farming #genetransfer #HGT #DNA #bacteria #Symbioses #nutientstransfer #AMF #nutrients #Crispr #herbideresistance #Glomalin #CO2 #CO2change #N #P #boreal	

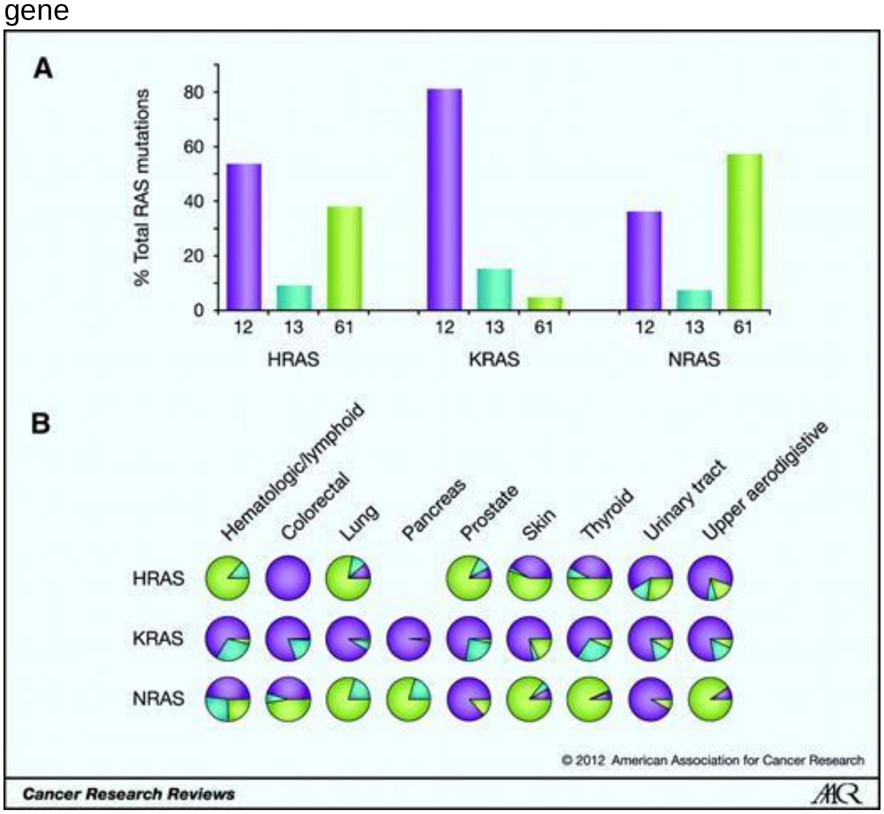
Article #1 Notes: RAS mutations in cancer

Article notes should be on separate sheets

KEEP THIS BLANK AND USE AS A TEMPLATE

Source Title	A comprehensive survey of Ras mutations in cancer
Source citation (APA Format)	Prior, I. A., Lewis, P. D., & Mattos, C. (2012). A comprehensive survey of Ras mutations in cancer. *Cancer Res 72* (10), 2457–2467. Doi: https://doi.org/10.1158/0008-5472.CAN-11-2612
Original URL	https://doi.org/10.1158/0008-5472.CAN-11-2612
Source type	Article
Keywords	RAS protein
#Tags	#RAS protein #microbiology #biology #cancer
Summary of key points + notes (include methodology)	This article from PubMed Central discusses RAS mutations in cancer and how the mutations in isoforms vary among themselves and different types of cancers. The RAS proteins promote cell signaling and growth, and when mutated and activated they promote oncogenesis with unregulated cell division. Understanding RAS genes and proteins is essential towards future methods of battling cancer with cancer research. RAS proteins are encoded with three closely related genes: HRAS, KRAS and NRAS. These proteins are GTP-ases that when activated by GTP create the proteins in signaling pathways that control cell growth. When the GTP binding site is mutated the GTPase-activating proteins (GAP) that inactivated the gene cannot properly bind. This leads to the RAS gene being constantly active, leading to unregulated cell division and creating a tumor. RAS isoforms experience different coupling to specific cancers, as well as the codons and substitutions generating the mutations. For example, KRAS mutations experience 43% G-A mutations at the second base of codon 12 or 13, resulting in G12D or G13D mutations. Almost the rest of the mutations are G-T to produce G12V mutations. NRAS exhibits this at a significantly lower rate. However, HRAS favors mutations at codon 12 to form G12V mutations at a significantly higher rate then both KRAS and NRAS. Also, 80% of all KRAS mutations occur at codon 12, whereas 60% of NRAS are at codon 61, and 50% codon 12 and 40% codon 61 split for HRAS. Even more interestingly are the different percentages of mutations for specific cancers. 90% of pancreatic cancer tumors have KRAS mutations, while hematopoietic tumors are primarily NRAS mutations. One of the reasons for this are the genotoxic agents causing the RAS

<table>
<tr><td></td><td>mutations. For example, methylnitrosourea (MNU) targets the second base of codon 12 of HRAS and KRAS in many cancers and UV radiation targets pyrimidine dimers resulting in RAS Q61 mutations. The exposure to the particular mutagens results in the specific mutation patterns shown between the isoforms across the different types of cancers. This, however, doesn’t explain the differences between RAS isoforms found within the same mutation. There is little experimental analysis on the potential reasons; however, it is speculated from collective data that the differences in the DNA primary sequence, the secondary to quaternary structural effects, and the position of the genes improve or limit the mutagens or repair enzymes access to the isoform. The RAS isoforms also code for different phenotypic responses, supporting the growth of cancer in various ways. KRAS is the most capable of sustaining cancer growth and development, which leads to greater pressure for cancer mutations of this particular isoform.</td></tr>
<tr><td>Research Question/Problem/ Need</td><td>What mutations create cancer, and how do they do so?</td></tr>
<tr><td>Important Figures</td><td>This figure shows the percentages of RAS mutations in difference cancers and the percent of where mutations happen in each RAS gene



</td></tr>
</table>

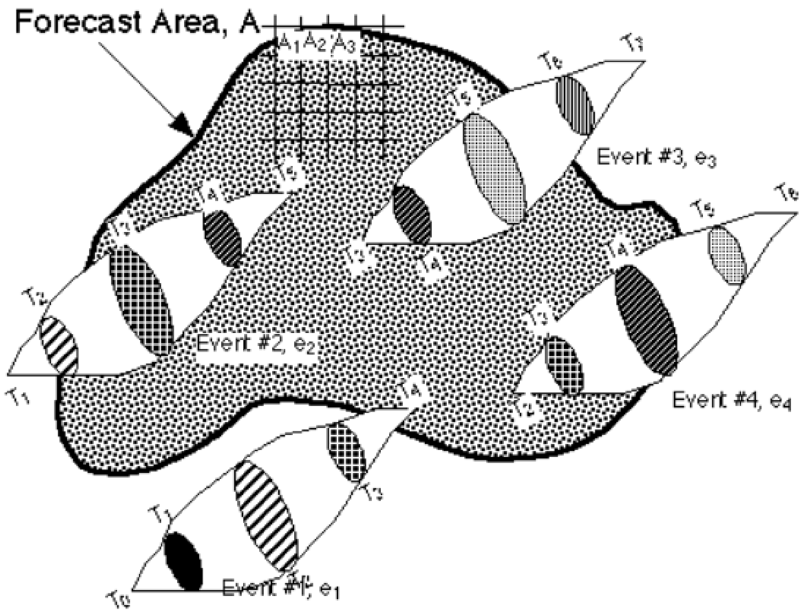
VOCAB: (w/definition)	Isoforms: gene products that are similar but different in function or form
Cited references to follow up on	Gorfe AA, Grant BJ, McCammon JA. Mapping the nucleotide and isoform-dependent structural and dynamical features of Ras proteins. Structure. 2008;16(6):885–96.
Follow up Questions	Can RAS mutations be reversed in order to stop cancer? How do RAS proteins interact in cells? How do RAS proteins vary in structure? What are the different phenotypic responses, and how do they result in different cancers?

Article #2 Notes: Probability in forecasting

Article notes should be on separate sheets

Source Title	Probabilistic forecasting - A Primer
Source citation (APA Format)	Doswell, C., & Brooks, H. (n.d.). Probabilistic forecasting - A Primer.Doi: https://www.nssl.noaa.gov/users/brooks/public_html/prob/Probability.html
Original URL	https://www.nssl.noaa.gov/users/brooks/public_html/prob/Probability.html
Source type	Online source
Keywords	Percent of precipitation
#Tags	#probability #forcasting #weather
Summary of key points + notes (include methodology)	This article describes how probability can be used to create polychotomous forecasts, more than two possible outcomes, and accurately predict dangerous weather: severe thunderstorms, tornados,

	etc. The website explains Bayes' theorem and how to forecast mutually related events: one event occurring depends on a certain event happening first. The article also mentions the importance of verifying the predictions made, which proves to be troublesome as it raises a lot of questions due to probabilistic forecasts having significantly more outcomes compared to dichotomous forecasts. Another issue that arrives when forecasting is the area and time period being forecasted. A large area with a large time period will have a near 100% forecast, while a small area and time period will be close to zero. Therefore, it is important to take into consideration the time and area of your forecast. For large amounts it should be attempted to pinpoint areas of high probability within our forecast area and period. If this is impossible, it is best to spread lower probabilities over a wide area. For small amounts climatology frequencies can be used. Climatology frequency uses past events for forecasting when there is little knowledge available. Finally, the article explains how to find the average probability of an event in the area we are forecasting, as events often don't happen in the entirety of the area. This is accomplished by splitting the forecast area into sub-areas, and averaging the probability of the event happening in the area. This also makes it easier to validate the forecast after the event happens. In summary, the article shows how mathematics can be used to predict seemingly unpredictable events, furthering our understanding of how mathematics and the world constantly interact.
Research Question/Problem/ Need	How can we use probability to predict seemingly unpredictable things like nature?

Important Figures	 Diagram shows how events span across the forecasted area, showing a realistic description of how forecasting looks
VOCAB: (w/definition)	PoP- percent of precipitation Polychotomous – more than two possible outcomes Dichotomous – two outcomes
Cited references to follow up on	N/A
Follow up Questions	Can technology, like AI be used to make more accurate forecasts than humans? Can the forecasting reading technology be improved? Can we use forecasting to prevent human casualties before natural disastors?

Article #3 Notes: the Quantum Origin of the Greenhouse Effect With Carbon Dioxide

Article notes should be on separate sheets

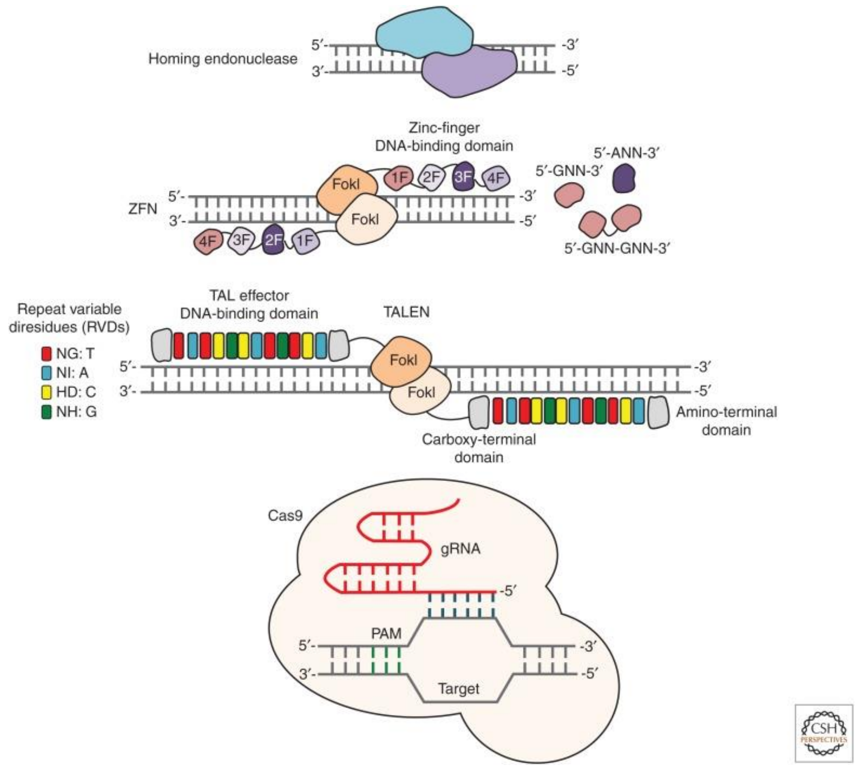
Source Title	Physicists Pinpoint the Quantum Origin of the Greenhouse Effect
Source citation (APA Format)	Howlett, J., Levin, J., Wolchover, N., & Savitsky, Z. (2024b, August 7). *Physicists pinpoint the quantum origin of the greenhouse effect*. Quanta Magazine. https://www.quantamagazine.org/physicists-pinpoint-the-quantum-origin-of-the-greenhouse-effect-20240807/
Original URL	https://www.quantamagazine.org/physicists-pinpoint-the-quantum-origin-of-the-greenhouse-effect-20240807/
Source type	News Article
Keywords	Carbon dioxide, greenhouse effect
#Tags	#chemistry #globalwarming #environment
Summary of key points + notes (include methodology)	This article talks about how carbon dioxide's quantum structure elevates carbon dioxide's ability to drive the greenhouse effect. The phenomenon in which carbon dioxide traps heat in Earth's atmosphere was discovered by Swedish physicist Svante Arrhenius in 1896. However, the physical reason why carbon dioxide behaves this way would remain unknown until recently. Carbon dioxide can absorb wavelengths slightly shorter or longer than 15 microns, though not as effectively as 15 microns. This range is atypical to other molecules in our atmosphere. When light gets absorbed, the molecule of carbon dioxide can either send it back to Earth or into space. The greenhouse effect is experienced when carbon dioxide sends absorbed light to Earth. Creating a logarithmic scale, as the number of molecules of carbon dioxide doubles, a two to five

	degree temperature rise of the Earth's temperature occurs. Carbon dioxide's unique contribution to global warming is due to its ability to absorb light within a range. A unique phenomenon called Fermi resonance explains that when a photon of 15-micron light is absorbed by carbon dioxide, the light sends the carbon atom swirling at the center point. When this energy of the first motion is doubled, another motion is formed where the two oxygen atoms bob towards and away from the carbon atom. When energy slightly more or less of the first motion is absorbed, hence the importance of carbon dioxide's ability to absorb wavelengths marginally shorter or longer of 15 microns, a new combined motion is created. When carbon dioxide experiences this combined motion, it releases the energy, creating the greenhouse effect. This explains the quantum mechanics behind carbon dioxide's contribution to global warming.
Research Question/Problem/ Need	How does Carbon dioxide contribute to the global warming effect?
Important Figures	N/A
VOCAB: (w/definition)	Microns: unit of measurement used for small molecules
Cited references to follow up on	N/A
Follow up Questions	Can energy be stopped from being absorbed by carbon dioxide? Can carbon dioxide be removed from the environment? Can carbon dioxide be binded with another molecule to prevent the movement mentioned in the article

Article #4 Notes:

Article notes should be on separate sheets

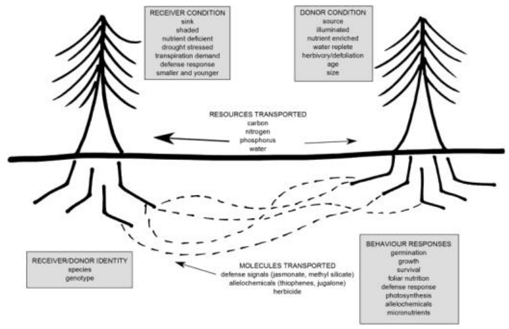
Source Title	Genome-Editing Technologies: Principles and Applications
Source citation (APA Format)	Prior, I. A., Lewis, P. D., & Mattos, C. (2012). A comprehensive survey of RAS mutations in cancer. *Cancer Research*, *72*(10), 2457–2467. https://doi.org/10.1158/0008-5472.can-11-2612
Original URL	https://doi.org/10.1158/0008-5472.CAN-11-2612
Source type	Journal article
Keywords	Genome
#Tags	#biology #geneediting
Summary of key points + notes (include methodology)	Gene editing, the ability to modify genomic sequences, has expanded scientists' ability to conduct experiments and studies and promoted the possibility of gene therapy. This article studies three technologies that laid the foundation of gene editing: CRISPR-Cas9, TALE nucleases, and zinc-finger nucleases. This article contrasts these three methods and discusses the benefits and disadvantages of using each one. They do this by pulling data from failures and successes of the different types to identify their differences. Overall, CRISPR-Cas9 seemed to be the best as it had the lowest failing rate, best overall success, and the least amount of risk of harming the organism being edited on.
Research Question/Problem/ Need	How are gene editing technologies able to function?
Important Figures	Diagram showing how gene editing works on the molecular level with targeted nucleases

	
VOCAB: (w/definition)	Targeted nucleases – allows the editor to target specific areas
Cited references to follow up on	Burt A. 2003. Site-specific selfish genes as tools for the control and genetic engineering of natural populations. Proc Biol Sci 270: 921–928. [PMC free article] [PubMed] [Google Scholar] Chakraborty S, Ji H, Kabadi AM, Gersbach CA, Christoforou N, Leong KW. 2014. A CRISPR/Cas9-based system for reprogramming cell lineage specification. Stem Cell Rep 3: 940–947. [PMC free article] [PubMed] [Google Scholar]
Follow up Questions	How can these technologies be expanded upon to limit potential unwanted mutations? Is it ethical to use gene editing on humans even if it prevents deadly diseases? Can gene editing be used to fix mutations in cancerous cells?

Article #5 Notes: mycorrhizal networks communication

Article notes should be on separate sheets

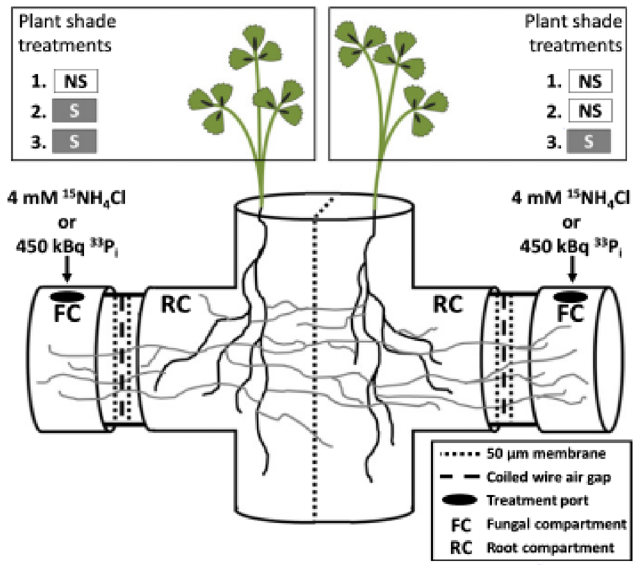
Source Title	Inter-plant communication through mycorrhizal networks mediates complex adaptive behaviour in plant communities
Source citation (APA Format)	Gorzelak, M. A., Asay, A. K., Pickles, B. J., & Gorzelak, S. W. (2015). Inter-plant communication through mycorrhizal networks mediates complex adaptive behaviour in plant communities . *AoB PLANTS*, *7*. https://doi.org/https://doi.org/10.1093/aobpla/plv050
Original URL	https://doi.org/10.1093%2Faobpla%2Fplv050
Source type	Journal article
Keywords	Complex adaptive systems, ectomycorrhiza, forests, mycorrhizal networks, plant behaviour, plant communication
#Tags	#mycorrhizal networks
Summary of key points + notes (include methodology)	This article reviews how plants reaction to different stimuli effect the plants within its network. When plants experience stimuli such as nutrient enrichment, stress, etc., it will send out signaling molecules. These signalling molecules are received by connected plants, allowing them to react accordingly. This is important because it shows how plants rely on their relationships with other plants to survive. They did this by comparing data between different previous research to draw large conclusions about these networks. This is done with a fungi called Mycorrhizae, and these fungi have different classes that are preferred. For example, AMF or Arbuscular mycorrhizal fungi is dominate in temperate grasslands, tropical forests and agricultural systems.
Research Question/Problem/ Need	How do environmental stimuli effect signaling in mycorrhizal networks
Important Figures	This diagram shows the different reactions of plants to different stimuli

	 This table provides data proving that the plants are reacting to the stimuli received in the network
VOCAB: (w/definition)	hub trees: central of the forest network allelochemical: chemical released by an organism that affects the growth and development of other organisms foliar : relating to leaves
Cited references to follow up on	Baleshta KE, Simard SW, Guy RD, Chanway CP. 2005. Reducing paper birch density increases Douglas-fir growth rate and Armillaria root disease incidence in southern interior British Columbia. *Forest Ecology and Management* 208:1–13. 10.1016/j.foreco.2004.07.076 Deslippe JR, Simard SW. 2011. Below-ground carbon transfer among *Betula nana* may increase with warming in Arctic tundra. *New Phytologist* 192:689–698. 10.1111/j.1469-8137.2011.03835.x
Follow up Questions	What are the best ways to model a mycorrhizal network? How do different environmental changes effect the rate at which the networks function? Is it possible for plants to send DNA through these networks?

Article #6 Notes: Carbon's effect on mycorrhizal networks

Article notes should be on separate sheets

Source Title	**Fungal nutrient allocation in common mycorrhizal networks is regulated by the carbon source strength of individual host plants**
Source citation (APA Format)	**Fellbaum, C., Mensah, J., Cloos, A., Strahan, G., Pfeffer, P., Kier, T., & Beucking, H. (2014). Fungal nutrient allocation in common mycorrhizal networks is regulated by the carbon source strength of individual host plants.** ***New Phytologist, 203,*** **646–656. doi: 10.1111/nph.12827**
Original URL	**10.1111/nph.12827**
Source type	**Journal article**
Keywords	**arbuscular mycorrhizal, mutualism, fungus, Carbon**
#Tags	#mycorrhizal networks #Carbon #CMNmodel
Summary of key points + notes (include methodology)	This article shows how carbon effects the symbiosis of plant networks. The used a chamber with mesh to prevent roots from moving, and they then gave 33p and 15n and measured their movements. Using isotopic analyses, they found that the result was that the plants with more carbon had more of the isotopes found.

Research Question/Problem/ Need	How does the symbiosis of mycorrhizal networks change as the Plant's Carbon varies?
Important Figures	 **Fig. 1** The custom-made growth system. A double membrane with an air gap (two sheets of 50-µm nylon mesh divided by a 30-cm-long wire spiral) prevented the diffusion of nutrients from the fungal compartment (FC) to the root compartment (RC), but allowed fungal hyphae to cross from the RCs into the FCs. Three different shade treatments were applied to the plants: (1) both nonshaded (NS/NS), (2) one nonshaded and one shaded (NS/S), and (3) both shaded. To the FCs, 4 mM $^{15}NH_4Cl$ or 450 kBq ^{33}P-orthophosphate was added. This is a model that I could potentially use in my project
VOCAB: (w/definition)	**Symbiosis: when two plants benefit each other's survival** **Ammonium: modified form of ammonia that has an extra hydrogen atom** **Putative: generally considered or reputed to be**
Cited references to follow up on	**St-Arnaud M, Hamel C, Vimard B, Caron M, Fortin JA. 1996. Enhancedhyphal growth and spore production of the arbuscular mycorrhizal fungusGlomus intraradices in an in vitro system in the absence of host roots.Mycological Research 100: 328–332.Takanishi I, Ohtomo R, Hayatsu M, Saito M. 2009. Short-chain polyphosphatein arbuscular mycorrhizal roots colonized by Glomus spp.: a possible phosphatepool for host plants. Soil Biology & Biochemistry 41: 1571–1573.Tanaka Y, Yano K. 2005. Nitrogen delivery to maize via mycorrhizal hyphaedepends on the form of N supplied. Plant, Cell & Environment 28: 1247–1254.**

Follow up Questions	**How would this change as CO_2 in the air changes? What is the rate that this occurs? Is this true for other fungi?**

Patent #1 Notes: Using Networks in widescale farming.

Article notes should be on separate sheets

Source Title	Application method of arbuscular mycorrhizal fungus in large-scale tobacco cultivation
Source citation (APA Format)	郭涛, 习向银. (2013). *Application method of arbuscular mycorrhizal fungus in large-scale tobacco cultivation* (China Patent No. CN103125251B). China Patent Agency. https://patents.google.com/patent/CN103125251B/en?q=(Mycorrhizal+fungi)&oq=Mycorrhizal+fungi
	https://patents.google.com/patent/CN103125251B/en?q=(Mycorrhizal+fungi)&oq=Mycorrhizal+fungi
Source type	**patent**
Keywords	**Mycorrhizal networks, tobacco, farming cultivation**
#Tags	#MN #farming #biology
Summary of key points + notes (include methodology)	This patent is for a method where they took a MN and used it to improve tobacco to coerce environment adaptability, improve tobacco leaf middle and upper part ratio. The idea is that this would make farming easier and more efficient. They grew the fungi separately, then introduced it to the plants. One network was given a fungicide as the control. When they introduced different diseases, they found the plants with the MN had greater success in their desired categories listed above due to the plants with the MN always having greater nutrients with the diseases than without.

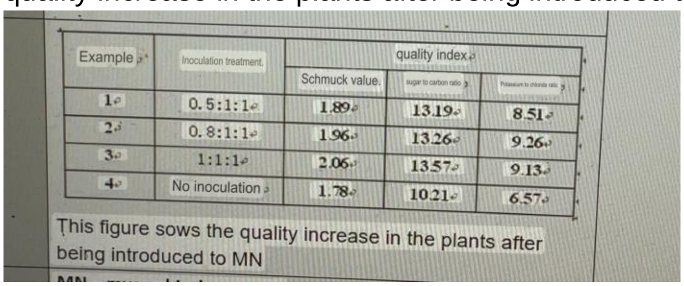
Research Question/Problem/ Need

Can MN be used in widescale farming to improve the cultivation of plants.

Important Figures

实施例	接种处理	品质指标		
		施木克值	糖碱比	钾氯比
1	0.5:1:1	1.89	13.19	8.51
2	0.8:1:1	1.96	13.26	9.26
3	1:1:1	2.06	13.57	9.13
4	不接种菌剂	1.78	10.21	6.57

This figure sows the quality increase in the plants after being introduced to MN



Example	Inoculation treatment	quality index		
		Schmuck value	sugar to carbon ratio	Potassium to chloride ratio
1	0.5:1:1	1.89	13.19	8.51
2	0.8:1:1	1.96	13.26	9.26
3	1:1:1	2.06	13.57	9.13
4	No inoculation	1.78	10.21	6.57

This figure sows the quality increase in the plants after being introduced to MN

*Chinese translation

VOCAB: (w/definition)

MN – mycorrhizal networks
Arbuscular mycorrhizal networks – a type of MN where the fungi goes directly into the cell
Inoculation - the action of immunizing someone against a disease by introducing infective material, microorganisms, or vaccine into the body

Cited references to follow up on

王发园, 石兆勇, 徐晓锋, 常会庆, 苗艳芳**. (2010).** ***Method for reducing heavy metal residues in tobacco by use of arbuscular mycorrhizal fungi*** **(China Patent N0. CN102047808B). China Patent Agency. https://patents.google.com/patent/CN102047808B/en?q=(Mycorrhizal+fungi)&oq=Mycorrhizal+fungi**

丁效东, 李淑仪, 詹振寿, 王军. (2012). *Method for improving cold and disease resistance of tobacco* (China Patent NO. CN102613054A). China Patent Agency. https://patents.google.com/patent/CN102613054A/en?q=(Mycorrhizal+fungi)&oq=Mycorrhizal+fungi

Follow up Questions	**Is using MN in farming ethical? Will it not potentially give benefits to weeds? Will this ever be widely implicated with wide fear of GMOs. Can DNA be passed with a AMN**

Article #7 Notes: Different horizontal gene transfer (HGT) methods plants use

Article notes should be on separate sheets

Source Title	Horizontal gene transfer in the photosphere
Source citation (APA Format)	Van Elsas, J. D., Turner, S., & Bailey, M. J. (2003). Horizontal gene transfer in the phytosphere. *New Phytologist*, *157*(3), 525–537. https://doi.org/10.1046/j.1469-8137.2003.00697.x
Original url	https://doi.org/10.1046/j.1469-8137.2003.00697.x
Source type	**Journal article**
Keywords	**Gene transfer, HGT, DNA, Bacteria, plant cells**

<table>
<tr><td>#Tags</td><td>#genetransfer #HGT #DNA #biology</td></tr>
<tr><td>Summary of key points + notes (include methodology)</td><td>This article went over the different ways that plants have been identified to perform HGT. Bacteria are able to form a mating pair formation with Plant cells. This conjugation gene transfer would allow bacteria to intake plant cell DNA, which could then be inserted into another cell. There are different factors that drive HGT: the environment must be good for bacteria colonization and mixing, otherwise the bacteria will be unable to transfer. They used evidence from other experiments to reach this conclusion.</td></tr>
<tr><td>Research Question/Problem/ Need</td><td>What are the different ways plant cells horizontally transfer DNA?</td></tr>
<tr><td>Important Figures</td><td>
<table>
<tr><th>Species</th><th>Genomic component</th><th>Size (Mbp)</th><th>%GC</th><th>Accession number</th></tr>
<tr><td>Mesorhizobium loti MAFF 303099</td><td>Chromosome</td><td>7.0</td><td>62.7[1]</td><td>NC_002678</td></tr>
<tr><td></td><td>pMLa</td><td>0.35</td><td>59.3</td><td>NC_002679</td></tr>
<tr><td></td><td>pMLb</td><td>0.21</td><td>59.9</td><td>NC_002682</td></tr>
<tr><td>Sinorhizobium meliloti 1021</td><td>Chromosome</td><td>3.7</td><td>62.7</td><td>NC_003047</td></tr>
<tr><td></td><td>pSymA</td><td>1.4</td><td>60.4</td><td>NC_003037</td></tr>
<tr><td></td><td>pSymB[2]</td><td>1.7</td><td>62.4</td><td>NC_003078</td></tr>
<tr><td>Agrobacterium tumefaciens C58</td><td>Chromosome</td><td>2.8</td><td>59.4</td><td>NC_003062</td></tr>
<tr><td></td><td>Linear chromosome</td><td>2.1</td><td>59.3</td><td>NC_003063</td></tr>
<tr><td></td><td>pATC58</td><td>0.54</td><td>57.3</td><td>NC_003064</td></tr>
<tr><td></td><td>pTiC58</td><td>0.21</td><td>56.7</td><td>NC_003065</td></tr>
<tr><td>Brucella melitensis</td><td>Chromosome I</td><td>2.1</td><td>57</td><td>NC_003317</td></tr>
<tr><td></td><td>Chromosome II</td><td>1.2</td><td>57</td><td>NC_003318</td></tr>
<tr><td>Brucella suis</td><td>Chromosome I</td><td>2.1</td><td>57.2</td><td>NC_004310</td></tr>
<tr><td></td><td>Chromosome II</td><td>1.2</td><td>57.3</td><td>NC_004311</td></tr>
<tr><td>Ralstonia solanearum</td><td>Chromosome</td><td>3.7</td><td>67.0</td><td>NC_003295</td></tr>
</table>
Summary of fully sequenced genomes of plant-associated and other bacteria</td></tr>
<tr><td>VOCAB: (w/definition)</td><td>HGT – horizonal gene transfer
Conjugation - the temporary union of two bacteria or unicellular organisms for the exchange of genetic material.
enterobacteria - large family of Gram-negative bacteria</td></tr>
<tr><td>Cited references to follow up on</td><td>Bailey MJ, Lilley AK. 2002. Niche colonisation and the dispersal of bacteria and their genes in the natural environment. In: JM</td></tr>
</table>

	Bullock, RE Kenward, RS Hail, eds. Dispersal ecology. Oxford, UK: Blackwell Publishing Ltd. **Bale MJ, Fry JC, Day MJ. 1988. Novel method for studying plasmid transfer in undisturbed river epilithon. Applied and Environmental Microbiology 54: 2756 – 2758.**
Follow up Questions	**Can the bacteria then transfer that DNA back to a chosen plant cell? How can I control when the transfer happens? How can I control what is being transferred.**

Patent #2 Notes: Different horizontal gene transfer (HGT) methods plants use

Article notes should be on separate sheets

Source Title	USE OF SYNERGISTIC MICROORGANISMS AND NUTRIENTS TO PRODUCE SIGNALS THAT FACILITATE THE GERMINATION AND PLANT ROOT COLONIZATION OF MYCORRHIZAL FUNG IN PHOSPHORUS RICH ENVIRONMENTS
Source citation (APA Format)	Johnson, T. D. (2015). *Use of synergistic microorganisms and nutrients to produce signals that facilitate the germination and plant root colonization of mycorrhizal fungi in phosphorus rich environments* (U.S. Patent No. US9416061B2). U.S.

<table>
<tr><td></td><td>Patent and Trademark Office. https://patents.google.com/patent/US 416061B2/en?q=(%22Mycor rhizal+fungi%22)&oq=%22Mycorrhizal +fungi%22</td></tr>
<tr><td></td><td>https://patents.google.com/patent/US9416061B2/en?q=(%22Mycorrhizal+fungi%22)&oq=%22Mycorrhizal+fungi%22</td></tr>
<tr><td>Source type</td><td>Patent</td></tr>
<tr><td>Keywords</td><td>MN, microorganisms, bacteria, phosphorus, nutrients, synergism</td></tr>
<tr><td>#Tags</td><td>#MN #bacteria #biology</td></tr>
<tr><td>Summary of key points + notes (include methodology)</td><td>This project focuses on combining synergistic microorganisms to create signals that facilitate germination and plant root colonization of mycorrhizae fungi. The method patented, combinging phytate and microorganisms, trichoderma veriens fungus,bacillus amyloliquefaciens bacterium, and different mycorrhizae fungi placed so they colonize plant root, creates an effective association of MF with roots in phosphorous rich environments, improving soil aggregation and quality. They tested this invention with different Mycorrhizae propagules, to prove its effectiveness. (figure below) and found that their invention increased plant yield as they plants had more yield with it than without.

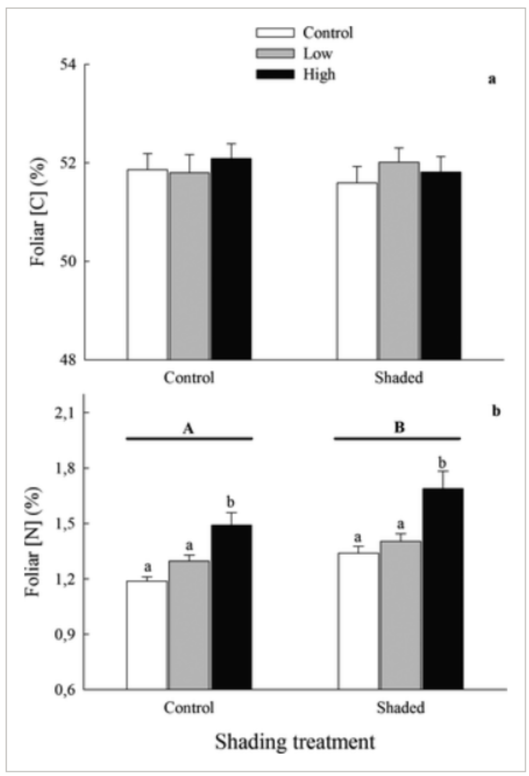
Arbuscular mycorrhizal fungi also have chemotaxic abilities which enable hyphal growth toward the roots of a potential host plant. - important info for project</td></tr>
<tr><td>Research Question/Problem/ Need</td><td>How does the change in mycorrhizal fungi composition affect plant yield?</td></tr>
<tr><td>Important Figures</td><td>
<table>
<tr><th>No.</th><th>Name</th><th>No Starter</th><th></th><th>Rank</th><th>10-34-0</th><th></th><th>Rank</th></tr>
<tr><td>1</td><td>CHK</td><td>121.05</td><td>g</td><td>7</td><td>135.37</td><td>cde</td><td>4</td></tr>
<tr><td>2</td><td>Myco IF</td><td>132.72</td><td>f</td><td>4</td><td>133.39</td><td>ef</td><td>5</td></tr>
<tr><td>3</td><td>Myco+T.V.+B.A. IF</td><td>129.22</td><td>ef</td><td>6</td><td>127.77</td><td>g</td><td>7</td></tr>
<tr><td>4</td><td>Phytate IF</td><td>130.96</td><td>ef</td><td>5</td><td>136.24</td><td>cde</td><td>3</td></tr>
<tr><td>5</td><td>Phytate+Myco IF</td><td>137.39</td><td>cd</td><td>3</td><td>132.11</td><td>ef</td><td>6</td></tr>
<tr><td>6</td><td>Phytate+T.V.+B.A. IF</td><td>144.57</td><td>ab</td><td>2</td><td>137.73</td><td>bcd</td><td>2</td></tr>
<tr><td>7</td><td>Phytate+Myco+T.V.+B.A. IF</td><td>147.44</td><td>a</td><td>1</td><td>146.39</td><td>a</td><td>1</td></tr>
<tr><td colspan="2">LSD (P=.10)</td><td colspan="2">4.274</td><td></td><td colspan="2">3.475</td><td></td></tr>
<tr><td colspan="2">Standard Deviation</td><td colspan="2">4.822</td><td></td><td colspan="2">3.921</td><td></td></tr>
<tr><td colspan="2">CV</td><td colspan="2">3.59</td><td></td><td colspan="2">2.92</td><td></td></tr>
</table>
Shows what mycorrhizal fungi composition creates the biggest yield</td></tr>
</table>

VOCAB: (w/definition)	Presymbiosis - the development of arbuscular mycorrhizal fungi prior to root colonization Synergistic - the microbial interaction in which both or all the microbial population involved gets benefitted, by supporting each other's growth and proliferation
Cited references to follow up on	Afek et al. Mycorrhizal species.root age-position of Mycorrhizal inoculum influence colonization of cotton.onion, pepper seedlings. J.Amer.Soc. Hort.Sci. 1990.938-942. 115(6).
Follow up Questions	**How should I change my mycorrhizal fungi composition to get the best rate of transfer? What mycorrhizal fungi composition would be able to transfer DNA? In what other ways does the mycorrhizal fungi composition affect a plant?**

Article #8 Notes: Nitrogen allocation effects on MN

Article notes should be on separate sheets

Source Title	Greater carbon allocation to mycorrhizal fungi reduces tree nitrogen uptake in a boreal forest
Source citation (APA Format)	Hasselquist, N. J., Metcalfe, D. B., Inselsbacher, E., Stangl, Z., Oren, R., Näsholm, T., & Högberg, P. (2016). Greater carbon allocation to mycorrhizal fungi reduces tree nitrogen uptake in a boreal forest. *Ecology*, *97*(4), 1012–1022. https://doi.org/10.1890/15-1222.1
Original url	https://doi.org/10.1890/15-1222.1

Source type	**Journal article**
Keywords	**ectomycorrhizal , symbioses, MN, nutrients transfer, EM**
#Tags	#MN #Symbioses #nutientstransfer
Summary of key points + notes (include methodology)	It is commonly assumed that MN gives N based on the amount of carbon that the host gives to the fungi. This study used large-scale shading treatment to reduce C supply, and gave 3 different levels of N with $^{15}NO_3^-$ to see how the different N amounts would affect the transfer of N. They found that the amount of Nitrogen given to the MF effected the amount of Nitrogen transferred to the plant, as the isotopic analysis showed a greater amount of N when the N nutrients given was greater.
Research Question/Problem/ Need	Does the transfer of nitrogen depend on the amount of carbon and nitrogen available to the MN?
Important Figures	 This figure shows how the amount given to the fungi changes the amount of nitrogen transferred.
VOCAB: (w/definition)	**MN – Mycorrhizal network** **EM - ectomycorrhizal symbioses**

	Ectomycorrhizal symbioses - a ubiquitous plant–fungus interaction in forests, evolved in parallel in fungi **mor-layer - forest humus that forms a layer of largely organic matter distinct from the mineral soil beneath** **Perfusate - a fluid used in perfusion.** **MF - Mycorrhizal fungi**
Cited references to follow up on	Albarracin, M. V., J. Six, B. Z. Houlton, and C. S. Bledsoe. 2013. A nitrogen fertilization field study of carbon-13 and nitrogen-15 transfers in ectomycorrhizas of *Pinus sabiniana*. *Oecologia* **173**: 1439–1450. Bahr, A., M. Ellström, C. Akselsson, A. Ekblad, A. Mikusinska, and H. Wallander. 2013. Growth of ectomycorrhizal fungal mycelium along a Norway spruce forest nitrogen deposition gradient and its effect on nitrogen leakage. *Soil Biology & Biochemistry* **59**: 38–48 Alberton, O., and T. W. Kuyper. 2009. Ectomycorrhizal fungi associated with Pinus sylvestris seedlings respond differently to increased carbon and nitrogen availability: implications for ecosystem responses to global change. Global Change Biology 15: 166–175.
Follow up Questions	**Would this explain the insignificantly different data found in the article 'Fungal nutrient allocation in common mycorrhizal networks is regulated by the carbon source strength of individual host plants'? How would this work for other nutrients? Does the amount of nitrogen effect other plants in the network?**

Article #9 Notes: Using MN networks in farming

Article notes should be on separate sheets

Source Title	Is there a role for arbuscular mycorrhizal fungi in production agriculture?
Source citation (APA Format)	Ryan, M. H., & Graham, J. H. (2002). Is there a role for arbuscular mycorrhizal fungi in production agriculture? *Plant and Soil*, *244*(1/2), 263–271. https://doi.org/10.1023/a:1020207631893
Original url	https://doi.org/10.1023/a:1020207631893
Source type	**Journal article**

Keywords

AMF, plant growth, nutrients, AM colonisation, farming

#Tags

#AMF #MN #farming #nutrients

Summary of key points + notes (include methodology)

This article argues that AMF does not greatly affect nutrition and growth of plants in production-orientated agricultural systems. They did this by taking different studies drawn that have proven high AMF effect, and stated different reasons that would have lead to this conclusion. They then went over the structure of AMF and why it wouldn’t work within the context of the experiment, and they generally hypothesized that nutrients levels effect nutrients intake much more than AMF. They also generally hypothesized that AMF effects are being over estimated due to use of field-based case studies, which would result in environment effecting results. They concluded that while AMF effect nutrients and growth, it is not to the degree that has been previously though.

Research Question/Problem/ Need

Does arbuscular mycorrhizal fungi effect the nutrition and growth of plants in production-orientated agricultural systems?

Important Figures

	Pre-treatment	Fertiliser P (kg ha^{-1})	AMF* (%)	Shoot biomass* (t ha^{-1})	Shoot P* (kg ha^{-1})	Yield (t ha^{-1})	Grain Zn (mg kg^{-1})
Wheat	Long fallow	None	46	0.95	2.0	3.3	21
	Linola	None	65	0.94	2.1	2.9	28
	Long fallow	20	12	2.42	6.6	4.8	14
	Linola	20	25	1.98	6.6	4.9	18
		$LSD_{0.05}$	13	0.40	1.4	0.5	2
Field pea	Long fallow	None	18	0.40	1.1	2.1	26
	Linola	None	41	0.45	1.3	2.0	35
	Long fallow	20	5	0.80	3.9	3.0	20
	Linola	20	10	0.80	3.2	3.4	24
		$LSD_{0.05}$	14	0.14	0.6	0.6	2

This figure shows the effect that percent of AMF has on plants.

VOCAB: (w/definition)

AMF - arbuscular mycorrhizal fungi
CMN – common mycorrhizal fungi
dazomet fumigant - soil fumigant that acts as a herbicide, fungicide, slimicide, and nematicide
Colonization- fungi growth

Cited references to follow up on

Thompson J P 1987 Decline of vesicular-arbuscular mycorrhizas in long fallow disorder of field crops and its expression in phosphorus deficiency in sunflower. Aust. J. Agric. Res. 38, 847–867.

	Thingstrup I, Rubæk G, Sibbesen E and Jakobsen I 1998 Flax (Linum usitatissimum L.) depends on arbuscular mycorrhizal fungi for growth and P uptake at intermediate but not high soil P levels in the field. Plant Soil 203, 37–46. Miller R M and Jastrow J D 2000 Mycorrhizal fungi influence soil structure. In Arbuscular Mycorrhizas: Physiology and Function. Eds. Y Kapulnik and D D Douds. pp. 3–18. Kluwer, Dordrecht.
Follow up Questions	**Are there any studies proving this to be true via experiments? If true, how will this effect my experiment? Is this also true of CMN?**

Article #10 Notes: CRISPR use in plants

Article notes should be on separate sheets

Source Title	Application of CRISPR/Cas9-mediated gene editing for the development of herbicide-resistant plants
Source citation (APA Format)	Han, Y.-J., & Kim, J.-I. (2019). Application of CRISPR/Cas9-mediated gene editing for the development of herbicide-resistant plants. *Plant Biotechnology Reports*, *13*(5), 447–457. https://doi.org/10.1007/s11816-019-00575-8
Original url	https://doi.org/10.1007/s11816-019-00575-8
Source type	**Journal article**
Keywords	**CRISPR/Cas9** **Gene editing** **Genome engineering** **Herbicide tolerance** **Crop improvement**
#Tags	#geneediting #Crispr #farming #herbideresistance
Summary of key points + notes (include methodology)	This article went through the different benefits of using genetically engineering. By genetically engineering farm plants to be resistant to the herbicide, it allows farmers to kill the weeds while allowing the plants to live. This article hypothesized several potential gene editing, CESA3 and SF3B1, that could be used to kill weeds. They tested this out by editing these genes in the plants (to make them HR) and then giving a non edited and an edited one herbicides. They found their hypothesis to be proven to be correct as the HR plants survived while the weeds died.

Research Question/Problem/ Need

Can herbicide resistance be used to increase farming productivity?

Important Figures

Herbicide	Gene	Gene product	Crop
2,4-D[b]	*AAD-1*	Aryloxyalkanoate dioxygenase-1 from *Delftia acidovorans*	Maize, soybean
Dicamba[c]	*DMO*	Dicamba monooxygenase from *Stenotrophomonas maltophilia* strain DI-6	Soybean
Glufosinate	*BAR*	Bialaphos resistance gene from *Streptomyces hygroscopicus*	Canola, chicory, cotton, maize, rice, soybean
	PAT	Phosphinothricin *N*-acetyltransferase from *Streptomyces viridochromogenes*	Canola, cotton, maize, soybean, sugar beet
Oxynil	*BXN*	Bromoxynil nitrilase from *Klebsiella pneumoniae* subsp. *ozaenae*	Canola, cotton, tobacco
Glyphosate	*GAT4601*	Glyphosate *N*-acetyltransferase from *Bacillus licheniformis*	Canola, Maize
	CP4EPSPS	An herbicide tolerant form of 5-enolpyruvylshikimate-3-phosphate synthase (EPSPS) from *Agrobacterium tumefaciens* strain CP4	Alfalfa, canola, cotton, creeping bentgrass, maize, potato, soybean, sugar beet, wheat
	2MEPSPS	A double mutant version (T102I/P106S) of EPSPS from *Zea mays*	Cotton, maize, soybean
	MEPSPS	A modified EPSPS (two amino acid substitutions) from *Zea mays*	Maize
Isoxaflutole	*HPPDPF W336*	A modified (G336W) *p*-hydroxyphenylpyruvate dioxygenase (HPPD) from *Pseudomonas fluorescens* strain A32	Cotton, soybean
Mesotrione	*AvHPPD-03*	An HPPD isozyme (missing A111) from *Avena sativa* (AvHPPD)	Soybean
Sulfonylurea	*SURB*	A mutant (P196A/W573L) of Acetolactate synthase (ALS) on locus *SuRB* from *Nicotiana tabacum*	Carnation

Currently known HR plants

VOCAB: (w/definition)

HR- herbicide-resistant
deregulation - the removal of regulations or restrictions, especially in a particular industry.

Cited references to follow up on

Ma X, Zhu Q, Chen Y, Liu YG (2016) CRISPR/Cas9 platforms for genome editing in plants: developments and applications. Mol Plant 9:961–974
Li J, Meng XB, Zong Y, Chen KL, Zhang HW, Liu JX, Li JY, Gao CX (2016) Gene replacements and insertions in rice by intron targeting using CRISPR-Cas9. Nat Plants 2:16139
Li Z, Liu ZB, Xing A, Moon BP, Koellhoffer JP, Huang L, Ward RT, Clifton E, Falco SC, Cigan AM (2015) Cas9-guide RNA directed genome editing in soybean. Plant Physiol 169:960–970

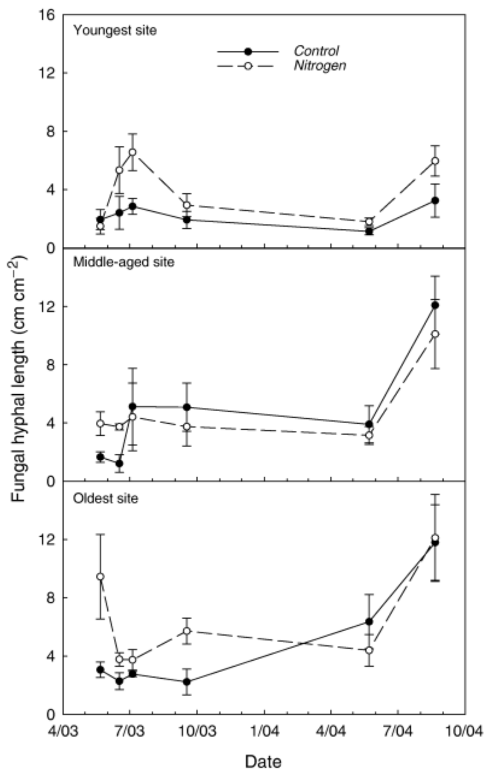
Follow up Questions

What are the potential risks of using gene editing? Would people want to use GMO's? Could I relate my project to farming benefits?

Article #11 Notes: Mycorrhizal responses to nitrogen fertilization in boreal ecosystems

Article notes should be on separate sheets

Source Title	Mycorrhizal responses to nitrogen fertilization in boreal ecosystems: potential consequences for soil carbon storage
Source citation (APA Format)	Treseder, K. K., Turner, K. M., & Mack, M. C. (2006). Mycorrhizal responses to nitrogen fertilization in boreal ecosystems: Potential consequences for Soil Carbon Storage. *Global Change Biology*, *13*(1), 78–88. https://doi.org/10.1111/j.1365-2486.2006.01279.x
Original url	https://doi.org/10.1111/j.1365-2486.2006.01279.x
Source type	**Article**
Keywords	**Mycorrhizal Fungi** **Nitrogen Fertilization** **Boreal Ecosystems** **Soil Carbon Storage** **Carbon Cycling** **Arbuscular Mycorrhizal Fungi (AMF)**
#Tags	#AMF #MN #boreal #nutrients #moleculetrasfer
Summary of key points + notes (include methodology)	- They used several boreal forest sites on Alaska and treated them to N fertilization, some left without as controls - Findings ○ Increase glomalin levels lead to reduction of 50 g C m^{-2} in total mycorrhizal carbon pools

	○ Increased the abundance of root AM structures across all sites, with large increase ECM structures, however no effect on soil AM hyphae ○ Carbon sequestering was modest compared to that in glomalin --> glomalin significant in soil carbon storage
Research Question/Problem/ Need	How will the abundance of mycorrhizal fungi and glomalin change under N fertilization in boreal ecosystems.
Important Figures	 Shows the length of the hyphal as the time goes on (**set up**)
VOCAB: (w/definition)	hyphal - filamentous structures that make up fungi glomalin - glycoprotein, or sugar-protein compound, that's produced by arbuscular mycorrhizal fungi in soil and plant roots boreal ecosystems - a large, northern forest biome
Cited references to follow up on	Driver, J. D., Holben, W. E., & Rillig, M. C. (2005). Characterization of glomalin as a hyphal wall component of arbuscular mycorrhizal fungi. *Soil Biology and*

	Biochemistry, *37*(1), 101–106. https://doi.org/10.1016/j.soilbio.2004.06.011 Friese, C. F., & Allen, M. F. (1991). The spread of VA mycorrhizal fungal hyphae in the soil: Inoculum types and external hyphal architecture. *Mycologia*, *83*(4), 409–418. https://doi.org/10.1080/00275514.1991.12026030 Klironomos, J., Rillig, M., Allen, M., Zak, D., Kubiske, M., & Pregitzer, K. (1997a). Soil fungal-arthropod responses to populus tremuloides grown under enriched atmospheric CO2 under field conditions. *Global Change Biology*, *3*(6), 473–478. https://doi.org/10.1046/j.1365-2486.1997.00085.x
Follow up Questions	**How would Glomalin work on plants not within a boreal forest? Would nitrogen fertilization improve this with all types of AM fungi? Was there any change in the structures of the fungi across the stages or site conditions**

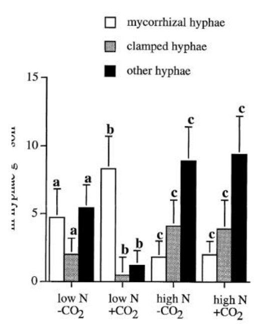
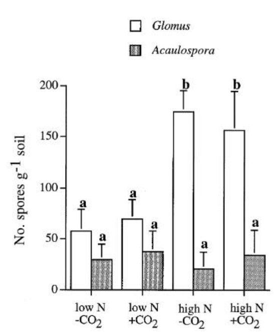
Article #12 Notes: Populus tremuloides with CO 2 under field conditions

Article notes should be on separate sheets

Source Title	Soil fungal-arthropod responses to Populus tremuloides grown under enriched atmospheric CO 2 under field conditions
Source citation (APA Format)	Klironomos, J., Rillig, M., Allen, M., Zak, D., Kubiske, M., & Pregitzer, K. (1997a). Soil fungal-arthropod responses to populus tremuloides grown under enriched atmospheric CO2 under field conditions. *Global Change Biology*, *3*(6), 473–478. https://doi.org/10.1046/j.1365-2486.1997.00085.x

Original url	https://doi.org/10.1046/j.1365-2486.1997.00085.x
Source type	**Article**
Keywords	**Soil Fungi** **Arthropod Communities** **Elevated CO_2** **Field Conditions** **Fungal Hyphae** **Soil Respiration**
#Tags	#mycorrhizal networks #Carbon #CMNmodel

Summary of key points + notes (include methodology)	- Took populus tremuloides and grew under two conditions ambient CO2 and elevated CO2. They then put in two different N treatments (limited N and enriched N) into the soil. They measured nutrient levels as well as plant and fungi growth.
	- Findings
	    ○ Low N
	        ▪ Elevated CO2 increased hyphal length by 77% for AM fungi
	    ○ High N
	        ▪ Reduced AMF by 71%, but more research found that they opposite relationship was true for non mycorrhizal fungi

Research Question/Problem/ Need	What is the influence of elevated CO2 and soil N availability on the growth of arbuscular mycorrhizal and non-mycorrhizal fungi, and on the number of mycophagoussoil microarthropods associated with the roots of Populus tremuloides?
Important Figures	

	Effect of CO_2 and N amount on the hyphae length of fungi
VOCAB: (w/definition)	- Arbuscular Mycorrhizal Fungi: A type of symbiotic fungi that form associations with plant roots, facilitating nutrient exchange (e.g., phosphorus) and receiving carbon from the host plant. - Hyphal Length: A measure of the total length of fungal filaments (hyphae) in a given volume of soil, reflecting fungal growth and activity. - Priming Effect: A phenomenon where increased microbial or fungal activity accelerates the decomposition of soil organic matter, potentially releasing stored carbon.
Cited references to follow up on	Oves, M., Hussain, F. M., Ismail, I. M. I., Felemban, N. M., & Qari, H. A. (2017). Microbiological carbon sequestration. *Advances in Environmental Engineering and Green Technologies*, 108–133. https://doi.org/10.4018/978-1-5225-2325-3.ch005 Bonito, G., Hameed, K., Ventura, R., Krishnan, J., Schadt, C. W., & Vilgalys, R. (2016). Isolating a functionally relevant guild of fungi from the root microbiome of populus. *Fungal Ecology*, *22*, 35–42. https://doi.org/10.1016/j.funeco.2016.04.007 Reddy, P. P. (2014). Impacts on plant pathogens. *Climate Resilient Agriculture for Ensuring Food Security*, 151–177. https://doi.org/10.1007/978-81-322-2199-9_8
Follow up Questions	**Why did AM increase hyphal length under low N and high CO_2? What drives this relationship? How does the reduction of the hyphal length affect the rest of the system? How does it affect the livelihood of the fungi?**

Article #13 Notes: Mycorrhizae with quantity of carbon allocated below ground changing

Article notes should be on separate sheets

Source Title	Mycorrhizae alter quality and quantity of carbon allocated below ground
Source citation (APA Format)	Rygiewicz, P. T., & Andersen, C. P. (1994). Mycorrhizae alter quality and quantity of carbon allocated below ground. *Nature*, *369*(6475), 58–60. https://doi.org/10.1038/369058a0
Original url	https://doi.org/10.1038/369058a0
Source type	**Article**
Keywords	**Mycorrhizae** **Carbon Allocation** **Below-Ground Carbon** **Fungal Hyphae** **Carbon Quality** **Root-Fungal Symbiosis** **Soil Organic Carbon** **Glomalin**
#Tags	#mycorrhizal networks #Carbon #CMNmodel #Glomalin

Summary of key points + notes (include methodology)	- Used colonized and non-colonized plants exposed to CO2 with 13C and then measured the carbon in above ground biomass and below ground
	- Findings
	    o Plants have more C allocation to below ground biomass (especially the roots and fungal hyphae)
	        ▪ Leads to increase below ground respiration and reduction of C above ground

	○ Carbon is directed towards carbon pools with rapid turnover rates (effects retention time C in soil) ○ Mycorrhizal influence quantity of carbon allocation below ground impacting soil carbon storage ○ Mycorrhizae are influenced by CO2
Research Question/Problem/ Need	How do mycorrhizal associations influence distribution of C allocated to Mycorrhizae?

Important Figures

Fraction	Non-inoculated	Ectomyc.	Non-inoculated	Ectomyc.
	Dry weight (mg)		Relative activity (Bq ^{14}C mg^{-1})	
Total plant	2,080	1,878*		
Above ground				
			Respiration	
Total	940	868*	50.0	44.0
			Remaining	
Bud and stem	266	238	20.0	22.4
Needles	674	630	27.0	27.0
Below ground				
			Respiration	
Total	1,137	1,010	15.3	22.1**
Roots (host)	1,137	910***	15.3	19.8
Active hyphae†	n.p.	100***	n.p.	40.1***
			Remaining	
Coarse roots	936	741**	14.6	17.7
Fine roots (host)	201	169	16.9	23.4*
Active hyphae	n.p.	100***	n.p.	32.8***

Values are means of numbers that were calculated using individual seedling data of ^{14}C allocation to fractions and the respective fraction dry weight. The individual seedling relative activity value was then standardized to 10^5 Bq total radioisotope assimilation by needles. All statistical conventions are as in Fig. 2. n.p., Not present.
† See Fig. 2 legend for estimates of hyphal mass in ectomycorrhizal root tips.

Fraction of dry weights and activity fractions based on carbon in the needles

VOCAB: (w/definition)

Hyphae - each of the branching filaments that make up the mycelium of a fungus.
Allocation - the action or process of distributing something.
Assimilation - movement of digested food into cells
Respiration - chemical process that releases energy from food

Cited references to follow up on

Dixon, R. K., Solomon, A. M., Brown, S., Houghton, R. A., Trexier, M. C., & Wisniewski, J. (1994). Carbon Pools and flux of global forest ecosystems. *Science*, *263*(5144), 185–190. https://doi.org/10.1126/science.263.5144.185

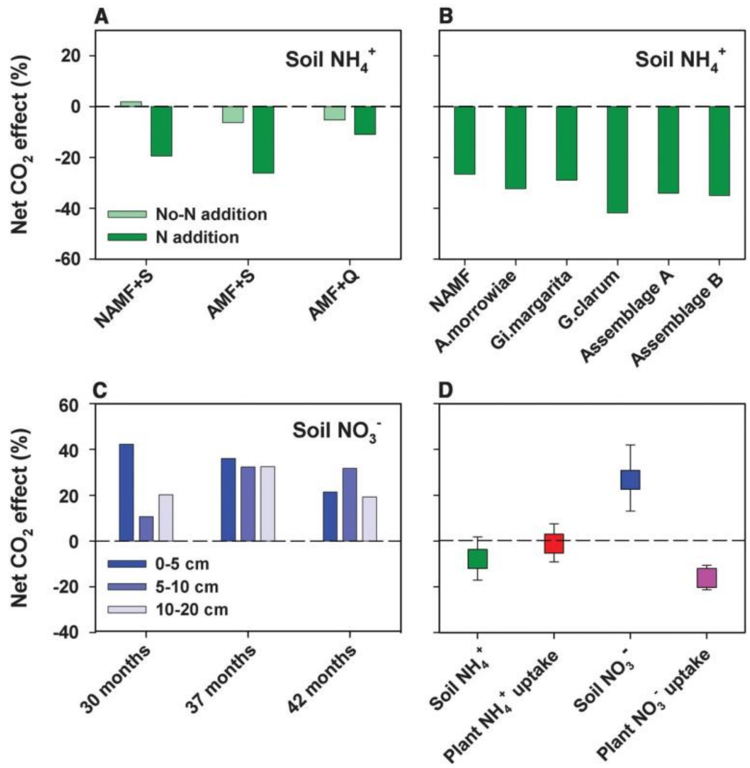
	Paul, E. A., & Kucey, R. M. (1981). Carbon flow in plant microbial associations. *Science*, *213*(4506), 473–474. https://doi.org/10.1126/science.213.4506.473 Rygiewicz, P. T., Miller, S. L., & Durall, D. M. (1988). A root-mycocosm for growing ectomycorrhizal hyphae apart from host roots while maintaining symbiotic integrity. *Plant and Soil*, *109*(2), 281–284. https://doi.org/10.1007/bf02202096
Follow up Questions	**Is there a CO2 level where this relationship because worse for the relationship? How does this relationship affect the environment indirectly (outside of the plants and fungi)? Are specific types of Mycorrhizal fungi more responsive to CO2?**

Article #14 Notes: How arbuscular mycorrhizal fungi increase organic carbon decomposition under elevated CO2

Article notes should be on separate sheets

Source Title	Arbuscular mycorrhizal fungi increase organic carbon decomposition under elevated CO2
Source citation (APA Format)	Cheng, L., Booker, F. L., Tu, C., Burkey, K. O., Zhou, L., Shew, H. D., Rufty, T. W., & Hu, S. (2012). Arbuscular mycorrhizal fungi increase organic carbon decomposition under elevated CO2. *Science*, *337*(6098), 1084–1087. https://doi.org/10.1126/science.1224304

Original url	https://doi.org/10.1126/science.1224304
Source type	**Article**
Keywords	**Arbuscular Mycorrhizal Fungi (AMF)** **Elevated CO_2** **Organic Carbon Decomposition** **Soil Carbon Dynamics** **Priming Effect** **Carbon Allocation** **Photosynthate Transfer**
#Tags	#mycorrhizal networks #CO2
Summary of key points + notes (include methodology)	- Control experiment with or without AM fungi inoculation. Plants were in growth chambers, one at ambient CO2 and one at elevated CO2, isotope 13C used). They measured Root colonization + hyphal length, soil respiration, and microbial biomass of soil carbon - Findings o Elevated CO2 levels increased the activity of AM, leading to more colonization of plant roots and hyphal network expansion o Elevated CO2 levels resulted in more soil carbon losses ▪ AM stimulation under elevated CO2 accelerated decomposition of C o Challenge the assumption that elevated CO2 enhanced plant growth and mycorrhizal activity, instead it stimulated AM to accelerate C decomposition
Research Question/Problem/ Need	How does elevated CO2 affect AM fungi in relation to soil carbon decomposition.

<table>
<tr><td>Important Figures</td><td>


Effect of CO2 on Nitrogen transfer within plants
</td></tr>
<tr><td>VOCAB: (w/definition)</td><td>Decomposition - the state or process of rotting; decay.
Grassland - biome where grasses are the dominant vegetation
Sequestration - process by which plants remove carbon from the atmosphere through photosynthesis
Saprotrophs - organism that feeds on nonliving organic matter known as detritus at a microscopic level</td></tr>
<tr><td>Cited references to follow up on</td><td>Drigo, B., Pijl, A. S., Duyts, H., Kielak, A. M., Gamper, H. A., Houtekamer, M. J., Boschker, H. T., Bodelier, P. L., Whiteley, A. S., Veen, J. A., & Kowalchuk, G. A. (2010). Shifting carbon flow from roots into associated microbial communities in response to elevated atmospheric CO2. Proceedings of the National Academy of Sciences, 107(24), 10938–10942. https://doi.org/10.1073/pnas.0912421107

Wilson, G. W., Rice, C. W., Rillig, M. C., Springer, A., & Hartnett, D. C. (2009). Soil aggregation and carbon sequestration are tightly correlated with the abundance of arbuscular mycorrhizal fungi: Results from long-term field</td></tr>
</table>

	experiments. *Ecology Letters*, *12*(5), 452–461. https://doi.org/10.1111/j.1461-0248.2009.01303.x Hodge, A., & Fitter, A. H. (2010). Substantial nitrogen acquisition by arbuscular mycorrhizal fungi from organic material has implications for N Cycling. *Proceedings of the National Academy of Sciences*, *107*(31), 13754–13759. https://doi.org/10.1073/pnas.1005874107
Follow up Questions	**Does C exchange benefit the plant or the fungi greater? How can soil carbon decomposition be elevated? What mechanism in AM lead to this happening?**

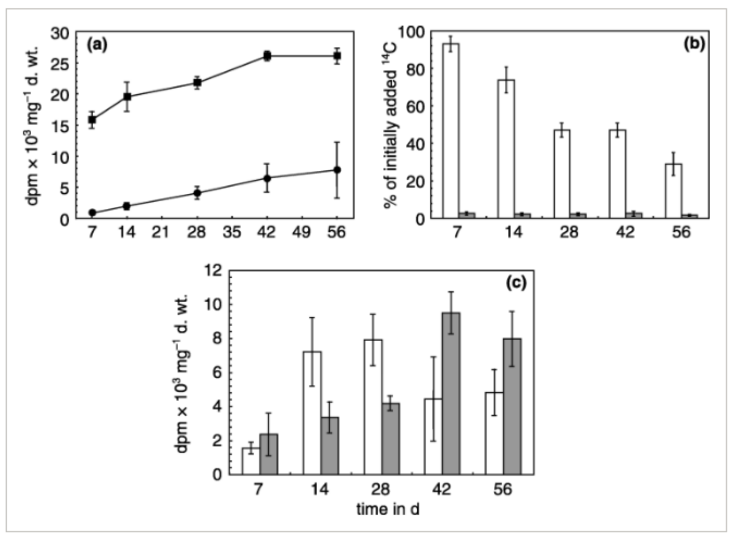
Article #15 Notes: mycorrhizal fungi and transferring carbon between plants.

Article notes should be on separate sheets

Source Title	The fungus does not transfer carbon to or between roots in an arbuscular mycorrhizal symbiosis
Source citation (APA Format)	Pfeffer, P. E., Douds, D. D., Bücking, H., Schwartz, D. P., & Shachar-Hill, Y. (2004). The fungus does not transfer carbon to or between roots in an arbuscular mycorrhizal symbiosis. *New Phytologist*, *163*(3), 617–627. https://doi.org/10.1111/j.1469-8137.2004.01152.x
Original url	https://doi.org/10.1111/j.1469-8137.2004.01152.x
Source type	**Article**
Keywords	**Arbuscular Mycorrhizal Fungi (AMF)** **Carbon Allocation** **Plant-Fungal Symbiosis** **Root Colonization** **Fungal Networks** **Carbon Flow**

#Tags	#mycorrhizal networks #Carbon #CMNmodel #CO2

Summary of key points + notes (include methodology)	- Plants grown with or without fungi, connected two plants with AM relationship, plants were then given 13C and isotopic analysis was used to identify carbon in fungi, soil, or plants
	- Findings
	    o They were unable to find significant movement of the C between the two plants, or the fungi and the neighboring plant
	    o They were unable to detect any 13C in the neighboring plants, but did in the fungi
	    o This shows that AM symbiosis does not do carbon transfer between plants, just uptakes for itself

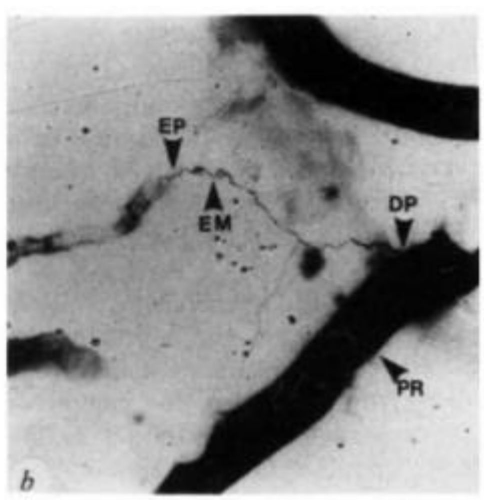
Research Question/Problem/ Need	Does AM f symbiosis facilitate transferring carbon between connected plants
Important Figures	 C content after roots receive glucose
VOCAB: (w/definition)	Medium - a substance that can transmit energy or light from one place to another fatty acids - chain-like molecules that make up fat in the body and food Biosynthetic metabolic pools - collective term for all of the substances involved in the metabolic process in a biological system

Cited references to follow up on	Bago, B., Pfeffer, P. E., Abubaker, J., Jun, J., Allen, J. W., Brouillette, J., Douds, D. D., Lammers, P. J., & Shachar-Hill, Y. (2003). Carbon export from arbuscular mycorrhizal roots involves the translocation of carbohydrate as well as lipid. *Plant Physiology*, *131*(3), 1496–1507. https://doi.org/10.1104/pp.102.007765 Bago, B., Pfeffer, P. E., Douds, D. D., Brouillette, J., Bécard, G., & Shachar-Hill, Y. (1999). Carbon metabolism in spores of the arbuscular mycorrhizal fungus glomus intraradices as revealed by nuclear magnetic resonance spectroscopy. *Plant Physiology*, *121*(1), 263–272. https://doi.org/10.1104/pp.121.1.263 Bidartondo, M. I., Redecker, D., Hijri, I., Wiemken, A., Bruns, T. D., Domínguez, L., Sérsic, A., Leake, J. R., & Read, D. J. (2002). Epiparasitic plants specialized on arbuscular mycorrhizal fungi. *Nature*, *419*(6905), 389–392. https://doi.org/10.1038/nature01054
Follow up Questions	**How does this affect the carbon symbiosis hypothesis I am researching? Does this carbon flow vary with fungi type? Could environmental conditions play a role in whether carbon is transferred or not?**

Article #16 Notes: Transfer of carbon between plants connected with AM

Article notes should be on separate sheets

Source Title	Direct transfer of carbon between plants connected by vesicular–arbuscular mycorrhizal mycelium.
Source citation (APA Format)	Francis, R., & Read, D. J. (1984). Direct transfer of carbon between plants connected by vesicular–arbuscular

	mycorrhizal mycelium. *Nature, 307*(*5946*), 53–56. https://doi.org/10.1038/307053a0
Original url	https://doi.org/10.1038/307053a0
Source type	**Article**
Keywords	**Carbon Transfer** **Mycorrhizal Networks** **Root Interconnections** **Plant-Fungal Symbiosis** **Photosynthate Allocation** **Isotope Labeling** **Common Mycorrhizal Networks (CMNs)**
#Tags	#mycorrhizal networks #Carbon #CMNmodel #CO2
Summary of key points + notes (include methodology)	- Two plants (donor and recipient) grown in same pots and colonized with fungi; control same expect no fungi. The Donor plant was given 14C through CO2. Isotopic radiation was used to see how much caron transferred - Findings o 14C was detected in the receiving plants in the experimental not in the control o This shows that carbon can be transfer between plans in a network
Research Question/Problem/ Need	Can carbon be transferred between plants in a mycorrhizal relationship?
Important Figures	

	Picture of fungi connecting with the roots of a plant
VOCAB: (w/definition)	Irradiation - the apparent extension of the edges of an illuminated object seen against a dark background. source-sink - location where resources are taken up or synthesized and used Inoculum - a substance used for inoculation. Autoradiographs - image on an X-ray film or nuclear emulsion produced by the pattern of decay emissions from a distribution of a radioactive substance
Cited references to follow up on	Heap, A. J., & Newman, E. I. (1980). The influence of vesicular-arbuscular mycorrhizas on phosphorus transfer between plants. *New Phytologist*, *85*(2), 173–179. https://doi.org/10.1111/j.1469-8137.1980.tb04458.x Chiariello, N., Hickman, J. C., & Mooney, H. A. (1982). Endomycorrhizal role for interspecific transfer of phosphorus in a community of annual plants. *Science*, *217*(4563), 941–943. https://doi.org/10.1126/science.217.4563.941 Cavagnaro, T., Gao, L., Smith, F., & Smith, S. (2001). Morphology of arbuscular mycorrhizas is influenced by fungal identity. *New Phytologist*, *151*(2), 469–475. https://doi.org/10.1046/j.0028-646x.2001.00191.x
Follow up Questions	**What factors affect the magnitude and direction of the transfer? Does carbon affect the recipient plant? How does carbon transfer differ from other molecular transfer?**

Article #17 Notes: effects of CO2 on mycorrhizal colonization

Article notes should be on separate sheets

Source Title	Effect of elevated atmospheric CO2 on mycorrhizal colonization, external mycorrhizal hyphal production and phosphorus inflow in Plantago lanceolata and Trifolium repens in association with the arbuscular mycorrhizal fungus Glomus mosseae
Source citation (APA Format)	Staddon, P. L., Fitter, A. H., & Graves, J. D. (1999). Effect of elevated atmospheric CO2 on mycorrhizal colonization, external mycorrhizal hyphal production and phosphorus inflow in plantago lanceolata and trifolium repens in association with the arbuscular mycorrhizal fungus Glomus Mosseae. *Global Change Biology*, *5*(3), 347–358. https://doi.org/10.1046/j.1365-2486.1999.00230.x
Original url	https://doi.org/10.1046/j.1365-2486.1999.00230.x
Source type	**Article**
Keywords	**Elevated CO_2** **Arbuscular Mycorrhizal Fungi (AMF)** **Glomus mosseae** **Mycorrhizal Colonization** **External Hyphal Production** **Phosphorus Inflow**
#Tags	#mycorrhizal networks #Carbon #CMNmodel #CO2 #CO2change
Summary of key points + notes (include methodology)	- Plants Plantago lanceolata (ribwort plantain) and Trifolium repens (white clover) inoculated with Glomus mosseae to establish relationship. Then two conditions of CO2 exposed too Ambient CO_2 concentration (~350 ppm) and elevated CO_2 concentration (~700 ppm), simulating predicted future scenarios. phosphorus was then put in the soil (uptake measured as well as root and soil samples - Findings ○ Elevated CO2 led to increase in % of root length of AM fungus and higher density of the hyphae, however data analysis led to

find this data to be insignificant and do to plant size then direct CO2 effect
- Root phosphorous remained unchanged
- CO2 promotes plant growth but does not affect the relationship between the fungi and the plants.

Research Question/Problem/ Need

How does CO2 affect the symbiotic relationship between AM fungi and host plants?

Important Figures

elevated CO_2 treatment effect			
	Covariate	*p*-value	Direction
Total plant DW	age	**	increase
Shoot DW	age	**	increase
Root DW	age	***	increase
Root length	age	**	increase
Specific root length (SRL)	age	NS	NA
SRL	total plant DW	NS	NA
Root DW	shoot DW	NS	NA
Root DW	total plant DW	NS	NA

CO2 effect on plant growth

VOCAB: (w/definition)

Covariate - a variable that is related to a dependent variable and can be used to predict or explain it
Nonparametric - a type of statistical analysis that makes few or no assumptions about the distribution of the data being studied
Sequential - forming or following in a logical order or sequence
air turbulence - when air flows in a chaotic or random way, rather than smoothly in one direction
gas analyzer - scientific devices that measure the concentration of a particular gas in a mixture of multiple gases

Cited references to follow up on

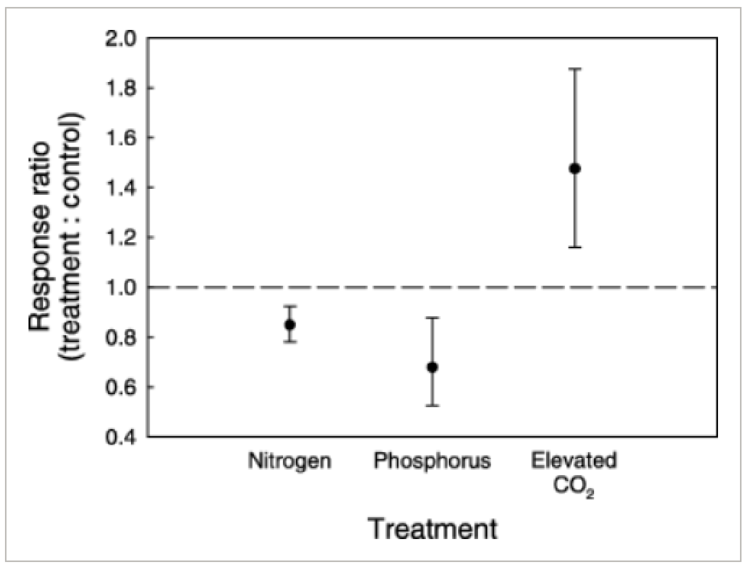
Emery, S. M., Bell-Dereske, L., Stahlheber, K. A., & Gross, K. L. (2022a). Arbuscular mycorrhizal fungal community responses to drought and nitrogen fertilization in switchgrass stands. *Applied Soil Ecology*, *169*, 104218. https://doi.org/10.1016/j.apsoil.2021.104218

Follow up Questions	**What was the difference identified between the two plant types? What would account for this? What plants are best when experimenting on nutrient transfer with AM fungi?**

Article #18 Notes: Mycorrhizal response to nutrients and CO2 variation

Article notes should be on separate sheets

Source Title	A meta-analysis of mycorrhizal responses to nitrogen, phosphorus, and atmospheric CO2 in field studies
Source citation (APA Format)	Treseder, K. K. (2004). A meta-analysis of mycorrhizal responses to nitrogen, phosphorus, and atmospheric CO2 in field studies. *New Phytologist*, *164*(2), 347–355. https://doi.org/10.1111/j.1469-8137.2004.01159.x
Original url	https://doi.org/10.1111/j.1469-8137.2004.01159.x
Source type	**Article**
Keywords	**Meta-Analysis** **Mycorrhizal Fungi** **Nitrogen Deposition** **Phosphorus Addition** **Elevated CO_2** **Field Studies** **Nutrient Cycling** **Plant-Fungal Symbiosis**
#Tags	#mycorrhizal networks #Carbon #CMNmodel #CO2 #N #P
Summary of key points + notes (include methodology)	- Conducted literary search and analysis to examine the effects of N and P additions as well as elevated CO2 on the AM fungi - Findings o Nitrogen additions

	▪ Fungi abundance decreased by 15% following nitrogen addition ▪ Suggests increasing nitrogen availability may reduce plants reliance on mycorrhizal relationship for nutrients o Phosphorus audients ▪ No significant effect found ▪ Not a limiting factor on fungi o Elevated CO2 ▪ Average increase of 47% in abundance for elevated CO2 ▪ May enhance plant carbon allocations, strengthening symbiotic relationships.
Research Question/Problem/ Need	How do different factors (N, P, and elevated CO2) affect mycorrhizal abundance?
Important Figures	 Responce of plants in relationship compared to that with CO2 and ones without
VOCAB: (w/definition)	Sporocarps - structures that produce and release spores in a variety of organisms, including fungi, aquatic ferns, and amoebozoans Abundance - a very large quantity of something meta-analyses - a statistical method that combines data from multiple studies to draw conclusions about a common research question

	Omitted - leave out or exclude (someone or something), either intentionally or forgetfully Nitrate - a compound of nitrogen and oxygen naturally found in air, soil, water, and some food
Cited references to follow up on	Cornwell, W. K., Bedford, B. L., & Chapin, C. T. (2001). Occurrence of arbuscular mycorrhizal fungi in a phosphorus-poor wetland and mycorrhizal response to phosphorus fertilization. *American Journal of Botany*, *88*(10), 1824–1829. https://doi.org/10.2307/3558359 Lukac, M., Caleapietra, C., & Godbold, D. L. (2003). Production, turnover and mycorrhizal colonization of root systems of three populus species grown under elevated co2 . *Global Change Biology*, *9*(6), 838–848. https://doi.org/10.1046/j.1365-2486.2003.00582.x Poorter, H. (1993). Interspecific variation in the growth response of plants to an elevated ambient CO2 concentration. *CO2 and Biosphere*, 77–98. https://doi.org/10.1007/978-94-011-1797-5_6
Follow up Questions	**Why does N reduce abundance? Is it only do to plants having access to N on its own? Why is this effect not**

Article #19 Notes: Fungi and plant response to CO2 increase

Article notes should be on separate sheets

Source Title	Taking mycocentrism seriously: Mycorrhizal fungal and plant responses to elevated co2
Source citation (APA Format)	Alberton, O., Kuyper, T. W., & Gorissen, A. (2005). Taking mycocentrism seriously: Mycorrhizal fungal and plant

	responses to elevated co2. *New Phytologist*, *167*(3), 859–868. https://doi.org/10.1111/j.1469-8137.2005.01458.x
Original url	https://doi.org/10.1111/j.1469-8137.2005.01458.x
Source type	**Article**
Keywords	**Mycocentrism** **Arbuscular Mycorrhizal Fungi (AMF)** **Ectomycorrhizal Fungi (ECM)** **Elevated CO_2** **Carbon Allocation** **Fungal Abundance** **Plant-Fungal Symbiosis**
#Tags	#mycorrhizal networks #Carbon #CMNmodel #CO2 #CO2change

Summary of key points + notes (include methodology)	- They put plants in a relationship with both ECM and AM they conducted experiments under elevated CO2 levels and ambient to simulate future atmospheric conditions
	- They then measured for fungal colonization, biomass, and hyphal and plant growth as well as isotopic labeling 13c for movement of carbon
	- Findings
	  ○ Elevated CO_2 resulted in a significant increase in abundance.
	  ○ ECM fungi exhibited a 34% increase in abundance, AM fungi showed a 21% increase
	    ▪ bigger response in ECM fungi
	  ○ No significant difference in growth
	  ○ ECM found monocentric perspective, but not in AM
	    ▪ ECM and AM have different dynamics related to carbon
	  ○ Elevated CO2 may alter the balance of carbon allocation + nutrient transfer differently in ECM and AM networks

Research Question/Problem/ Need	How do AM fungi and ECM fungi react to elevated CO2 with abundance and activity?

Important Figures

Categories	*R*	95% CI	*n*	*P*
AM plants	1.25	1.19–1.31	74	
ECM fungi	1.34	1.25–1.45	65	0.17
ECM plants	1.26	1.19–1.34	65	
AM fungi	1.21	1.12–1.32	77	0.32
AM plants	1.25	1.19–1.31	74	
ECM extraradical	1.45	1.30–1.65	38	< 0.01
ECM colonization percentage	1.19	1.09–1.28	31	
AM extraradical	1.23	1.07–1.40	46	0.65
AM colonization percentage	1.17	1.06–1.30	30	
ECM extraradical	1.45	1.30–1.65	38	0.04
AM extraradical	1.23	1.07–1.40	46	
ECM extraradical	1.45	1.30–1.65	38	0.03
ECM plants	1.26	1.19–1.34	65	
AM plants	1.25	1.19–1.31	74	0.55
AM extraradical	1.23	1.07–1.40	46	

Meta-analysis of the effects of elevated CO2 on mycorrhizal systems

VOCAB: (w/definition)

meta-analysis - a statistical process that combines data from multiple studies to draw conclusions about a topic
Ozone - gas made up of three oxygen atoms
PLFA - phospholipid fatty acids
extraradical mycelium - a network of fungal hyphae that extends from the roots of plants into the soil

Cited references to follow up on

Gavito, M. E. (2000). Atmospheric CO2 and mycorrhiza effects on biomass allocation and nutrient uptake of nodulated pea (Pisum sativum L.) plants. *Journal of Experimental Botany*, *51*(352), 1931–1938. https://doi.org/10.1093/jexbot/51.352.1931

Hu, S., Wu, J., Burkey, K. O., & Firestone, M. K. (2005). Plant and Microbial N acquisition under elevated atmospheric CO2 in two mesocosm experiments with annual grasses. *Global Change Biology*, *11*(2), 213–223. https://doi.org/10.1111/j.1365-2486.2005.00905.x

	Lussenhop, J., Treonis, A., Curtis, P. S., Teeri, J. A., & Vogel, C. S. (1998). Response of soil biota to elevated atmospheric CO 2 in Poplar Model Systems. *Oecologia*, *113*(2), 247–251. https://doi.org/10.1007/s004420050375
Follow up Questions	**Why do ECM fungi have a stronger response to elevated CO2? How does increased fungal abundance under the elevated CO2 affect the fungi's nutrient uptake? Is using ECM more beneficial than AM?**

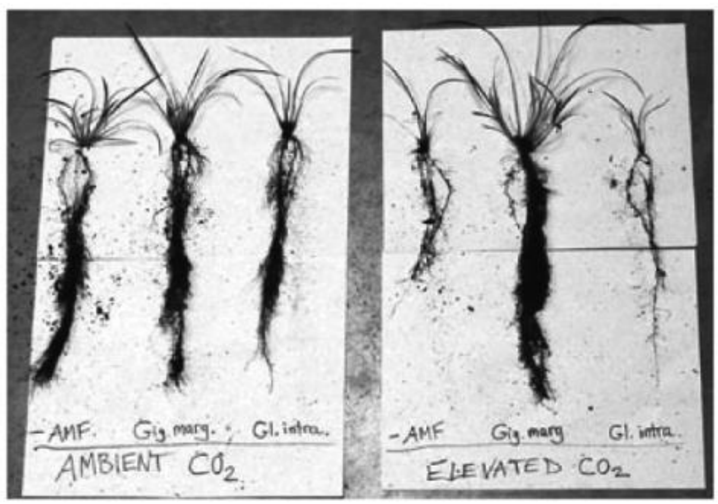
Article #20 Notes: plants associated with working with mycorrhizal fungi and CO2 icnrease

Article notes should be on separate sheets

Source Title	Species of plants and associated arbuscular mycorrhizal fungi mediate mycorrhizal responses to CO2 enrichment
Source citation (APA Format)	Johnson, N. C., Wolf, J., Reyes, M. A., Panter, A., Koch, G. W., & Redman, A. (2005). Species of plants and associated arbuscular mycorrhizal fungi mediate mycorrhizal responses to CO2 enrichment. *Global Change Biology*, *11*(7), 1156–1166. https://doi.org/10.1111/j.1365-2486.2005.00967.x
Original url	https://doi.org/10.1111/j.1365-2486.2005.00967.x
Source type	**Article**
Keywords	**Arbuscular Mycorrhizal Fungi (AMF)** **Symbiotic Relationships** **Elevated CO_2** **Plant-Fungal Interactions** **Carbon Allocation**

	Nutrient Uptake
#Tags	#mycorrhizal networks #Carbon #CMNmodel #CO2 #CO2change

Summary of key points + notes (include methodology)	- Plants were inoculated in paring, with multiple different species used. They were then grown under ambient CO2 (current atmospheric levels) and elevated CO2 (predicted levels) They ten measured plant growth and 13C allocation between test and control
	- Findings
	  o Different plants exhibited different responses to the fungi
	  o This shows that plant chosen matters
	  o CO2 increased the nutrient uptake amounts (it therefore enhances mutualistic benefits of the fungi)

Research Question/Problem/ Need	How do specific plants react to AM fungal relationism?
Important Figures	 Root length of plants grown with different fungi in different CO2 conditions
VOCAB: (w/definition)	- Species-Specific Effects: The unique responses and interactions that occur based on the identity of plant and fungal species in a symbiotic relationship. - Symbiotic Specificity: The degree to which a particular plant and fungal species form an exclusive or preferential symbiotic relationship.

	- Hyphal Network: The extensive web of fungal filaments (hyphae) in the soil that connects plant roots and facilitates the transfer of nutrients and carbon. - Mutualism-Dependency Gradient: A continuum describing the degree to which plants rely on mycorrhizal fungi for nutrient acquisition, ranging from high mutualism (mutually beneficial) to low dependency (minimal reliance).
Cited references to follow up on	Diaz, S. (1995). Elevated co 2 responsiveness, interactions at the community level and plant functional types. Journal of Biogeography, 22(2/3), 289. https://doi.org/10.2307/2845923 Fitter, A. H., Heinemeyer, A., & Staddon, P. L. (2000). The impact of Elevated Co2 and global climate change on Arbuscular Mycorrhizas: A mycocentric approach. *New Phytologist*, *147*(1), 179–187. https://doi.org/10.1046/j.1469-8137.2000.00680.x Gavito, Mayra E, Schweiger, P., & Jakobsen, I. (2002). P uptake by arbuscular mycorrhizal hyphae: Effect of soil temperature and atmospheric CO2 enrichment. *Global Change Biology*, *9*(1), 106–116. https://doi.org/10.1046/j.1365-2486.2003.00560.x
Follow up Questions	**Why do different plants react differently in the network? How do the fungi specifically benefit from receiving more carbon? Could environmental factors influence the relationship in this study?**