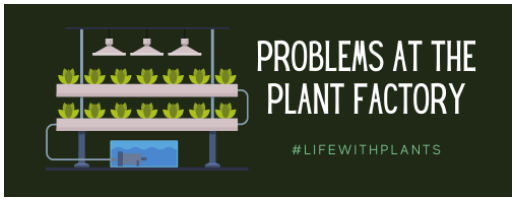

Overview: These lessons explore a phenomenon associated with light quality and its role in development of purple lettuce leaf color and plant morphology. Lessons may augment modules in, for example, Photosynthesis or the Biology of Skin Color (Melanin), and serve as a way to introduce careers in controlled-environment horticulture to high school students. The storyline uses data sets from published research.

Lesson & Question	Student Activities and Key Resources	Vocabulary	Biology Objectives- Evolution, Genetics, Ecology NGSS - DCIs, SEPs, & CCCs	Notes
1. What inputs for plant growth can be managed when plants are grown in a greenhouse or plant factory?	**Introduction videos:** Introduce hydroponics (lettuce, deep pool); Discovery Channel, How It's Made (4:45): https://www.youtube.com/watch?v=OrxwjwDaBR0 or https://www.youtube.com/watch?v=Wmq9SPPgUpc Introduce plant factories (vertical farms, controlled-environment agriculture): Vertical Farms Could Take Over the World | Hard Reset by Freethink (11:03) https://www.youtube.com/watch?v=J4SaSfnHK3I or Are Vertical Farms the Future of Agriculture? PBS Digital Studios, The Good Stuff. August 15, 2015. (10:42 in length if use 0:16 to 10:58): https://www.youtube.com/watch?v=Uh_zJ09jUc0 or	Hydroponics Plant factories Vertical farms CEA (controlled environment agriculture)	Asking questions (for science) and defining problems (for engineering) Developing and using models Systems and system models **HS-ESS3-3** Earth and Human Activity, Illustrate the relationships among the management of natural resources,	FOUNDATION – Have students make observations and generate questions from video, create an initial model.

	Why the Future of Farming is in Cities: The Big Money in Vertical Farming (11:34) https://www.youtube.com/watch?v=LiNI-JUFtsA **Activities to introduce storyline:** Develop Initial Model for managing plant growth in CEA or Build "I notice, I wonder, Could it be" or Build Driving Question Board: What factors must a grower consider when growing crops under artificial lights?		the sustainability of human populations, and biodiversity.	
2. How can light be variable?	**Class discussion:** What do light quantity, quality, and duration mean? What plant responses would these different aspects of light affect? In a Nutshell: What is Light? (4:38) https://www.youtube.com/watch?v=IXxZRZxafEQ or Professor Dave Explains: Light (3:55) https://www.youtube.com/watch?v=pj_ya0e20vE	Light quantity Light quality Light spectrum Light duration Ultra-violet light Far-red light	**PS3.A** Definitions of energy **HS-LS1-5** Illustrate how photosynthesis transforms light energy into stored chemical energy	FOUNDATION – An understanding of light characteristics is a necessary review to set the stage for exploring its biological effects.
3. What would happen if we grew plants under different light qualities?	**Class discussion about Figure 1, experimental design of data set [link]:** How do you expect the lettuce plants grown under these different light qualities to be different? **Optional: Introduce classroom experiment:** We want purple plants: students select which light quality will produce purple plants and place seedlings under high red, white, or high blue lamp [link] How Plants Use Light: Three LED Spectrums (12:38) https://www.youtube.com/watch?v=NMVP7Nvew0A	Morphology LEDs	Planning & carrying out investigations **HS-LS1.B** Growth & Development of Organisms **HS-LS1-6** How C, H, O combine with other elements to form amino acids or other large C-based molecules	Viewing the published research may be helpful for you and/or your students at some point in the lessons). The original manuscript and a trade journal version are available.

4. What makes leaves purple?	Students do a quick google search on 'anthocyanin' Understand how the presence of different pigments determine a plant's color (2:00) | Britannica https://www.britannica.com/video/152178/Sunlight-plants-chlorophyll-pigments-colouring **Class discussion about Figure 2: data set of experimental results with lettuce** (Meng and Runkle) [link] Researcher Interview 1 (Meng): What does the data mean? [link]	Genotype Phenotype Chlorophyll Anthocyanin Flavanoids Secondary metabolites	**HS-LS1-6** How C, H, O combine with other elements to form amino acids or other large C-based molecules Cause and effect	This lesson allows for discussion of genotype and phenotype. Only certain cultivars of lettuce will develop purple leaves, and these display phenotypic differences based on light quality in their environment.
5. Why are purple leaves desirable as food?	**Class discussion:** Why might a plant factory want purple plants? Students do a quick Google search for 'anthocyanin health benefits' Anthocyanidins and anthocyanins: colored pigments as food, pharmaceutical ingredients, and the potential health benefits: NIH National Library of Medicine https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5613902/	Antioxidants	Obtaining, evaluating, and communicating information	
6. How would I change the lighting to get purple plants? Or longer leaves? Or increased biomass?	Students develop a CER, Claim Evidence Reasoning, from data sets of leaf color, length, and biomass: **Figure 3 and Figure 4 from two genotypes** Scientific Explanation: write one, short paragraph. First sentence is claim (the answer). Use evidence (includes data; "increasing"). Put Reasoning into words. Researcher Interview 2 (Meng): How do you design experiments to study light quality? [link]		Planning and carrying out investigations Constructing explanations (for science)	The data sets link not only leaf color, but also leaf length and biomass development across two genotypes. This provides an opportunity to expand the conversation

				beyond leaf color to include light effects on morphology and biomass accumulation.
7. Wrap up and review	Wrap-up discussion: Demand and price for purple-leaved lettuce is higher than for green-leaved lettuce. The plant factory is producing only green-leaved lettuce. How should this problem be addressed? Find out more: Researcher Interview 3 (Meng): What skills are needed for future urban horticulturists? [link] What are careers in CEA? https://www.seedyourfuture.org/careers Next Jobs: The High-Tech Vertical Farmer: Bowery in NJ. Bloomberg Quicktake. https://www.youtube.com/watch?v=AGcYApKfHuY (8:13)		Engaging in argument from evidence	In the discussion, two solutions could be repeated from earlier lessons: 1) use a genotype of lettuce that will produce anthocyanins; and 2) subject the lettuce to high blue/UVA-B light at end of its production cycle.
NGSS Overview: Asking questions (for science) and defining problems (for engineering); Developing and using models; Planning and carrying out investigations; Analyzing and interpreting data; Constructing explanations (for science) and designing solutions (for engineering); Engaging in argument from evidence; Obtaining, evaluating, and communicating information Patterns; Cause and effect; Scale, proportion, and quantity; Systems and system models; Energy and matter; Structure and function; Stability and change. HS-LS1-2; HS-LS1-3; HS-LS1-5; HS-LS2-3; HS-LS2-5; HS-LS2-7 HS-ESS3-3 and HS- PS3.A provide opportunities for DCI overlap				