Citation Reference:

Huang, Y., Huang, Y., Liao, Q., Fu, Q., Xia, A., & Zhu, X. (2018). Improving phosphorus removal efficiency and Chlorella vulgaris growth in high-phosphate MFC wastewater by frequent addition of small amounts of nitrate. *Bioresource Technology*, *258*, 268-275.

Overall, Purpose of These Notes:

To deeply analyze the efficiency and mechanisms of phosphorus (P) removal by *Chlorella vulgaris* in wastewater, and its impact on algal growth and potential biomass production. This research will specifically inform the design and operational strategies for a hybrid flat panel and airlift bioreactor for wastewater treatment in low-income areas.

Core Research Questions & Answers:

- **1. Optimal Phosphorus Concentration for Growth & Removal:**
  - Phosphorus concentration in the wastewater was 14760 mg/L, which is 109 times higher than that of a normal microalga medium.
  - Furthermore, the nitrogen to phosphorus ratio was 1:73.
  - The pH (7.4) and the penetration of light in the wastewater were considered optimal factors for growth of *Chlorella vulgaris*.
  - However, due to initial nitrogen deficiency in the wastewater, algae growth was inhibited and efficient removal of phosphorus significantly decreased.
  - The highest phosphorus removal ratio was up to 37.22%. This occurred when a total amount of 2.0 g/L $NaNO_3$ was added with a feeding frequency of 0.5 g/L for 3 days.
- **Implication for My Design:**
  - This paper confirms that a proper ratio of N:P is highly important for *Chlorella vulgaris* growth and biomass production.
  - Some wastewaters have varying amounts of nitrates and phosphates, so my design should contain nitrogen supplementation for maximizing growth and phosphorus uptake.
- **2. Phosphorus Uptake Mechanisms & Kinetics:**
  - The "phosphorus content in microalgae biomass gradually increased from 1.2% to 3.5% (of dried mass) with increasing sodium nitrate concentrations (from 0.25 g/L to 1.0 g/L)." This shows *Chlorella* accumulated phosphorus in its cells.
  - "It demonstrated that relative nitrogen starvation could act as a trigger for higher phosphorus assimilation in *Chlorella vulgaris* when cultivated in nitrogen limited MFC wastewater." This suggests that a certain level of N limitation might stimulate the algae to take up and store P for immediate active growth.
  - This process is an example of Luxury uptake where plants or algae take up large concentrations of a specific nutrient more than immediately required for growth.

- **Implications for My Design:**
  - Luxury uptake by algae (phosphorus nutrient) can occur when nitrogen is scarce.
  - By doing this, the design could allow the algae to take up more phosphorus than is normally required by controlling the amount of nitrogen in the bioreactor.
  - The research mentions that 45.16 milligrams of phosphorus uptake occurs from every liter of water per day. This could help find the rate to calculate how big the bioreactor needs to be to clean a certain amount of wastewater and a specific amount of phosphorus-rich water daily.
  - *Chlorella vulgaris* can help store large amounts of phosphorus in the cell body (3.5% of the dried weight).
  - Once harvested manually from the reactor, the biomass itself becomes a valuable source. It can be used as fertilizer, which could, in turn, help cover the financial costs of maintaining the bioreactor.
- **Operational Parameters & Consistency in P Studies:**
  - Light intensity: 127 μmol photon m^{-2} s^{-1} (continuous illumination)
  - Temperature: 25°C
  - PH: Monitored daily (initial pH of MFC wastewater was 7.4, noted as suitable for *Chlorella* growth in a previous snippet).
  - Mixing/Aeration: Aeration with 10% CO_2 (v/v) at a rate of 50 mL min^{-1}.
  - Nutrient Feeding Strategy (Nitrogen): The study optimized $NaNO_3$ addition:
    - Initial concentrations tested were 0, 0.25, 0.5, 0.75, and 1.0 g L^{-1}.
    - Optimal feeding frequencies and amounts were tested, including 0.5 g L^{-1} every three days (to reach totals of 1.0, 1.5, and 2.0 g L^{-1}) and other frequencies like 0.125 g L^{-1} daily or 0.25 g L^{-1} every two days (to reach 1.0 g L^{-1} total).
  - CO2 Concentration: 10% (v/v) in the aeration gas.
- **Implication for My Design:**
  - A consistent temperature of 25°C.
  - Continuous illumination at 127 μmol photon m^{-2} s^{-1}.
  - A robust aeration system delivers 10% CO_2 at an appropriate flow rate (e.g., 50 mL min^{-1} for experimental scale). This also ensures adequate mixing.
  - A system for monitoring and potentially controlling pH to keep it in a suitable range.
  - Most importantly, a controlled nitrogen supplementation system capable of implementing the optimized feeding strategies (e.g., pulsed or staged addition of $NaNO_3$) to ensure the ideal N:P ratio for maximum phosphorus uptake and biomass growth.