H_2 production by anoxygenic purple nonsulfur bacteria

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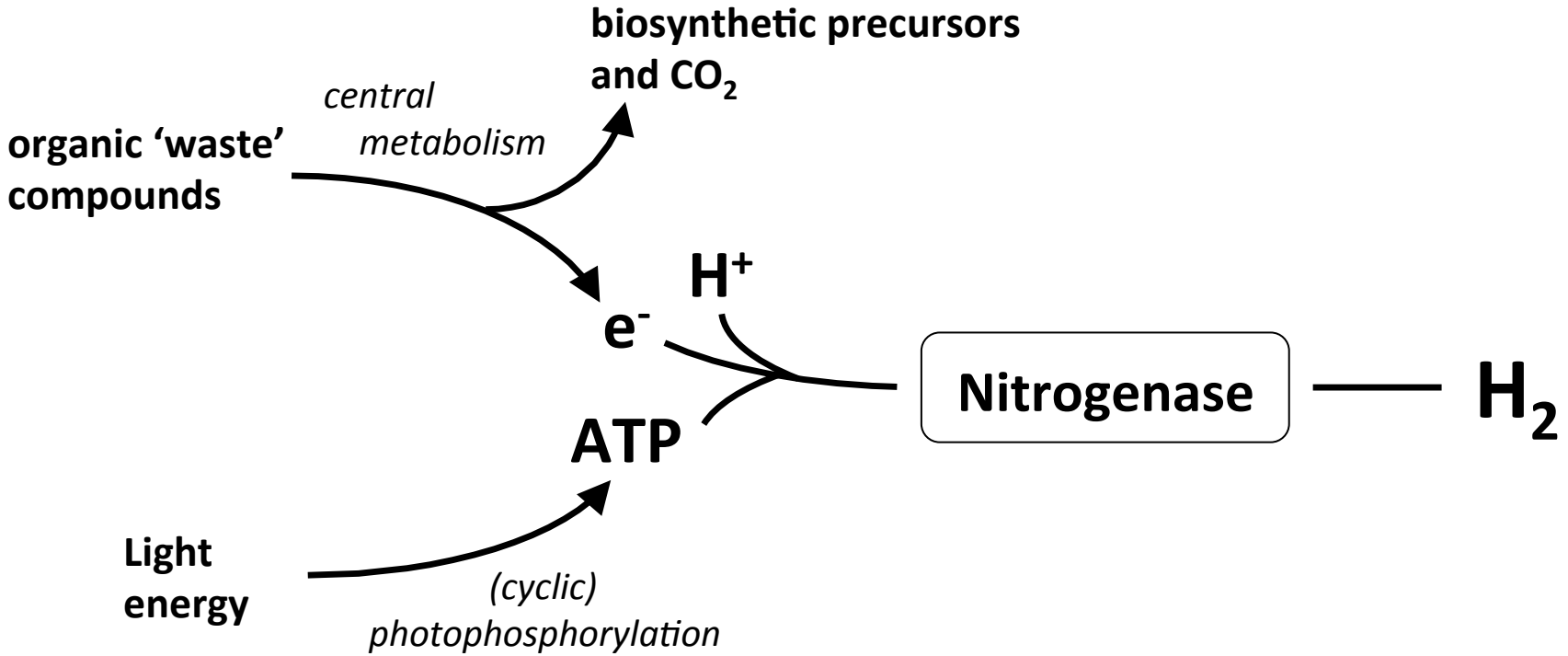
Purple non-sulfur bacteria produce H_2 via nitrogenase



$$N_2 + 8H^+ + 8e^- + 16ATP \rightarrow H_2 + 2NH_4^+$$

$$8H^+ + 8e^- + 16ATP \rightarrow 4H_2$$

This is mode of photosynthesis does not produce oxygen

Current state of the technology

- H_2 yields
  - Growing : 10 – 25% of theoretical maximum
  - Non-growing: 40 – 91% of theoretical maximum

- H_2 production rates
  - 10 – 82.5 ml H_2 L^{-1} h^{-}
  - 67 ml H_2 L^{-1} h^{-1} over 4000 h
    - Immobilized in 70 µm-thick latex film.

    Gosse et al. 2010. Biotechnol. Prog. 26: 907 – 18

- Photosynthetic efficiency: 1 – 2%
  - 6% Barbosa et al. 2001. J. Biotechnol. 85: 25-33

Reviewed by Brentner et al. 2010. Environ. Sci. Technol. 44: 2243-2254

Summary of barriers and important developments

- Inhibition of H_2 production by NH_4^+
  - Bypassed using *nifA** and DraT mutations

  (Rey et al. 2007 Appl Environ Microbiol 73: 1665-71, Zou et al. 2008 Microbiol 154: 2689-99, McKinlay and Harwood. 2010 PNAS 107: 11669-75, Heiniger et al. 2012 Appl Environ Microbiol 78: 1023-32)

- Other pathways that compete against H_2 production for electrons
  - e.g., Calvin cycle identified and eliminated

  (Wang et al. 2010 Int J H2 Energ 35: 7377-85, McKinlay and Harwood 2011 mBio 2)

- Biosynthesis efficiently competes against H_2 production
  - Understanding of non-growing cells that produce highest H_2 yields is improving (Huang et al. 2010. Appl. Environ. Microbiol. 76: 7717-22)

Summary of barriers and important developments

- Light penetration into cultures
  - Improved using pigment-defective strains
    (Gosse et al. 2007. Biotechnol. Prog. 23: 124-30)
  - Novel bioreactor designs (Posten 2009 Eng Life Sci 9:165-77)

- Integration with 'waste' feedstock streams
  - Consolidating fermentations with photosynthetic production of H_2

(Odom and Wall 1983 Appl Envrion Microbiol 45:1300-5; Melis and Melnicki 2006 31: 1563-73, Jiao et al. 2012 Int J H2 Energ 37: 11719-26)

Key Research needs

- System-wide approaches to understand genetic and metabolic factors involved in H_2 production, particularly H_2 production rate
- Examination of the physiology of non-exponential phase cells (e.g., starving cells, subpopulations, communities)
- Biological and physical solutions to address light limitation with scale up
  - Design principles of light harvesting units
  - Interactions with groups that offer physical solutions (e.g., light conducting plastics)