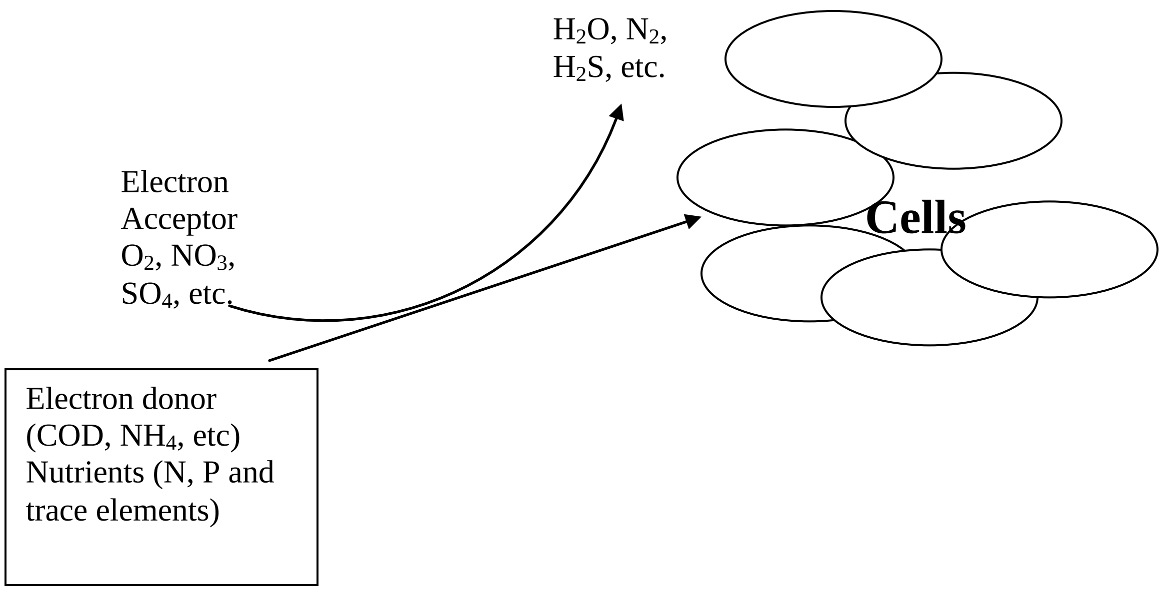
GROWTH-RELATED PROCESSES

Concepts:

Balanced growth: substrate (energy source, carbon source, nutrients, electron acceptors available). Cells use some substrate electrons for energy production (consuming electron acceptor) and some for synthesis of new cells.



In general

Energy for cell activities = substrate energy available – energy potential of cells

Yield

$$\text{YIELD} = \frac{\text{cell mass produced}}{\text{substrate consumed}} = Y$$

also

$$\text{YIELD} = \frac{\text{growth rate}}{\text{substrate consumptio nrate}} = Y$$

generally

$$0 < Y < 1$$

Units of Y:

Y(mass): $$\frac{g-\text{cells (dry weight)}}{g-\text{substratec ompound}} \quad \text{e.g.,} \frac{g-\text{cells}}{g-\text{glu cos e}}$$

Y(COD): $$\frac{g-\text{cell}-\text{COD}}{g-\text{COD consumed}} = \frac{1.42 * g-\text{cells}}{1.07 * g-\text{glu cos e}}$$

Y(e^-): $$\frac{g-\text{cell}-\text{COD}}{e^-}$$

Electron equivalent of COD from Oxygen reduction half-reaction:

$$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$$

Ratio: $$\frac{1*(32g)-O_2}{4e^-} = \frac{8g-O_2}{e^-} = \frac{8g-\text{substrate}-\text{COD}}{e^-}$$

$$Y(e^-) = 8*Y(COD)$$

For glucose:

$$Y(e^-) = 8*(1.42/1.07)*Y(mass) = 10.6\ Y(mass)$$

Where $Y(e^-) > 1$

Factors affecting yield:

Substrate type: Connelly et al found for heterotrophs

$$Y(\text{amino acids}) > Y(\text{sugars, alcohols}) > Y(\text{NOM})$$

$$Y(\text{autotrophs}) < Y(\text{heterotrophs})$$

$0.48 < Y(\text{COD, heterotrophs}) < 0.72$ (Grady et al)

$0.0.06 < Y(\text{COD/N, autotrophs}) < 0.35$ (Grady et al)

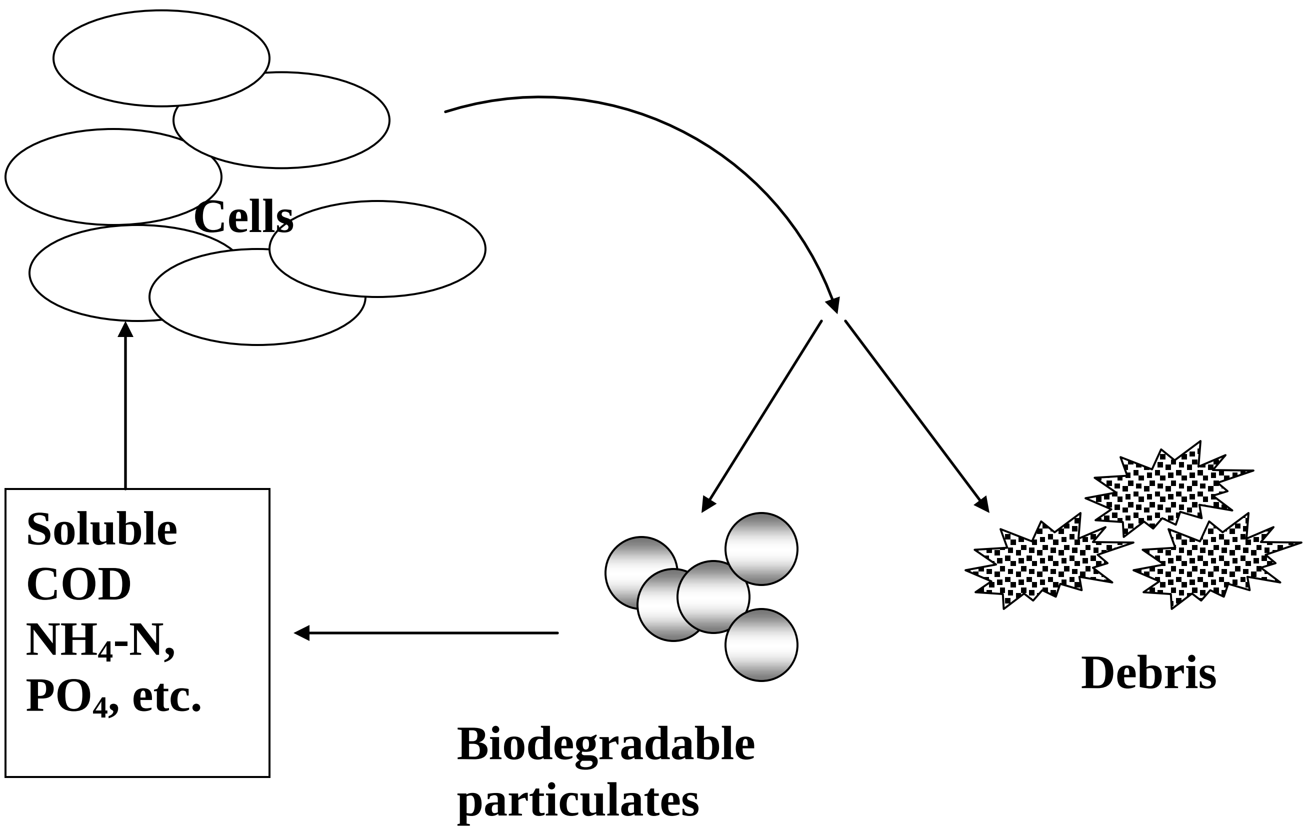
Electron acceptor:

$Y(\text{COD, aerobic}) > Y(\text{COD, denitrifiers}) > Y(\text{COD, fermenters})$

Growth Conditions:

Temperature
pH
species of organism

ACTIVITIES THAT DO NOT PRODUCE OR EVEN REDUCE GROWTH: MAINTENANCE ENERGY, DECAY AND CELL LYSIS, PREDATION



Maintenance energy used for: regeneration of enzymes, membrane integrity, motility, etc.

Use of Y in COD stoichiometry for cell <u>growth</u>:

$$\mathbf{COD - (1\text{-}Y)\ O_2 \rightarrow Y\ cell\text{-}COD}$$

Check: $1 - (1\text{-}Y) = Y$

Maintenance energy, decay, predation all reduce yield:

Define "observed yield" = $Y_{obs} < Y$

Example:

Let Y(COD) = 0.5 g cell COD/g-substrate COD consumed

Suppose 50% of biomass grown is lysed and 70% of lysed COD can be recovered as substrate.

$\mathbf{Y_{obs}}$ **=**	**0.5*Y(COD) +**	**0.5*Y(COD)*0.7**	**= 0.25 + 0.35*0.5 = 0.495**
	(Orig. Growth)	(lysed and recovered)	

Note that debris are non-viable particulate products of decay and accumulate in biomass, introducing concept of **viable fraction**.

KEY PROCESS IN DECAY CYCLE IN TREATMENT SYSTEMS: HYDROLYSIS

Extracellular enzymes hydrolyze biodegradable particulates to soluble COD.

Factors that affect hydrolysis and recovery of COD

Cell mass (to produce enzymes)
Diffusion of products

Two models for oxygen utilization for full growth-decay cycle:

1. Decay produces either debris or new cells directly (no hydrolysis). Secondary oxygen utilization in decay step for direct production of cells. Compartments: external COD source, cells, and debris

$$\text{COD} + O_2 \rightarrow \text{cell-COD}$$

$$\text{Cell-COD} + O_2 \rightarrow \text{cell-COD} + \text{debris-COD}$$

2. Decay produces either debris or biodegradable particulates, followed by hydrolysis. Oxygen utilization is only in the step soluble COD → cells. Compartments: substrate COD, cells, debris, and biodegradable particulates.

$$\text{Soluble COD} + O_2 \rightarrow \text{cell-COD}$$

$$\text{Cell-COD} \rightarrow \text{debris-COD} + \text{biodegradable particulate-COD}$$

Biodegradable particulate-COD → soluble COD

Advantages of second model.

- Accounts for influent particulate and soluble COD
- Allows for rapidly and slowly degradable COD
- Simplifies oxygen consumption calculation
- Probably more realistic.