Better Plants
U.S. DEPARTMENT OF ENERGY

VIRTUAL WASTEWATER INPLT

SESSION 4

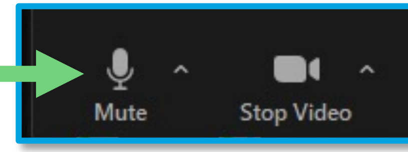
U.S. DEPARTMENT OF ENERGY

Using Zoom!

Mute yourself!

Have a question?
Use the chat feature.

Controls accessed at the bottom



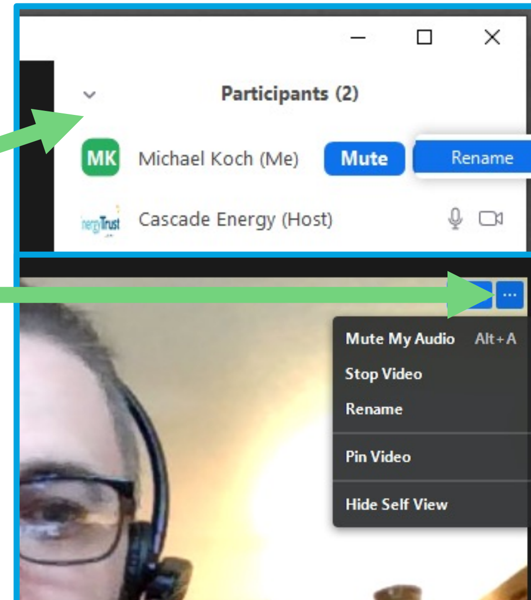
Rename yourself

"Name (Company)"

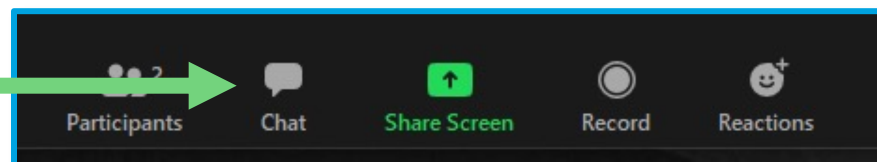
Right click on your picture or 3 dots

OR

Controls accessed at the right after clicking 'Participants' at bottom.



Access Chat at the bottom



Recording

This meeting is being recorded (both audio and video)

If you do not consent to being recorded, please let the meeting moderator know ASAP and we will facilitate your participation in another way or adjust our procedure.

Chat question for the week

- ***What has been your favorite vacation?***

Thank You!

Sponsor:

Better Plants
U.S. DEPARTMENT OF ENERGY

Today’s Agenda

Welcome and Introductions	Aeration Blower Opportunities
Plant Energy Basics	Fans & Odor Control
Bacterial Energetics and Aeration	Opportunity Jam
Break	Done

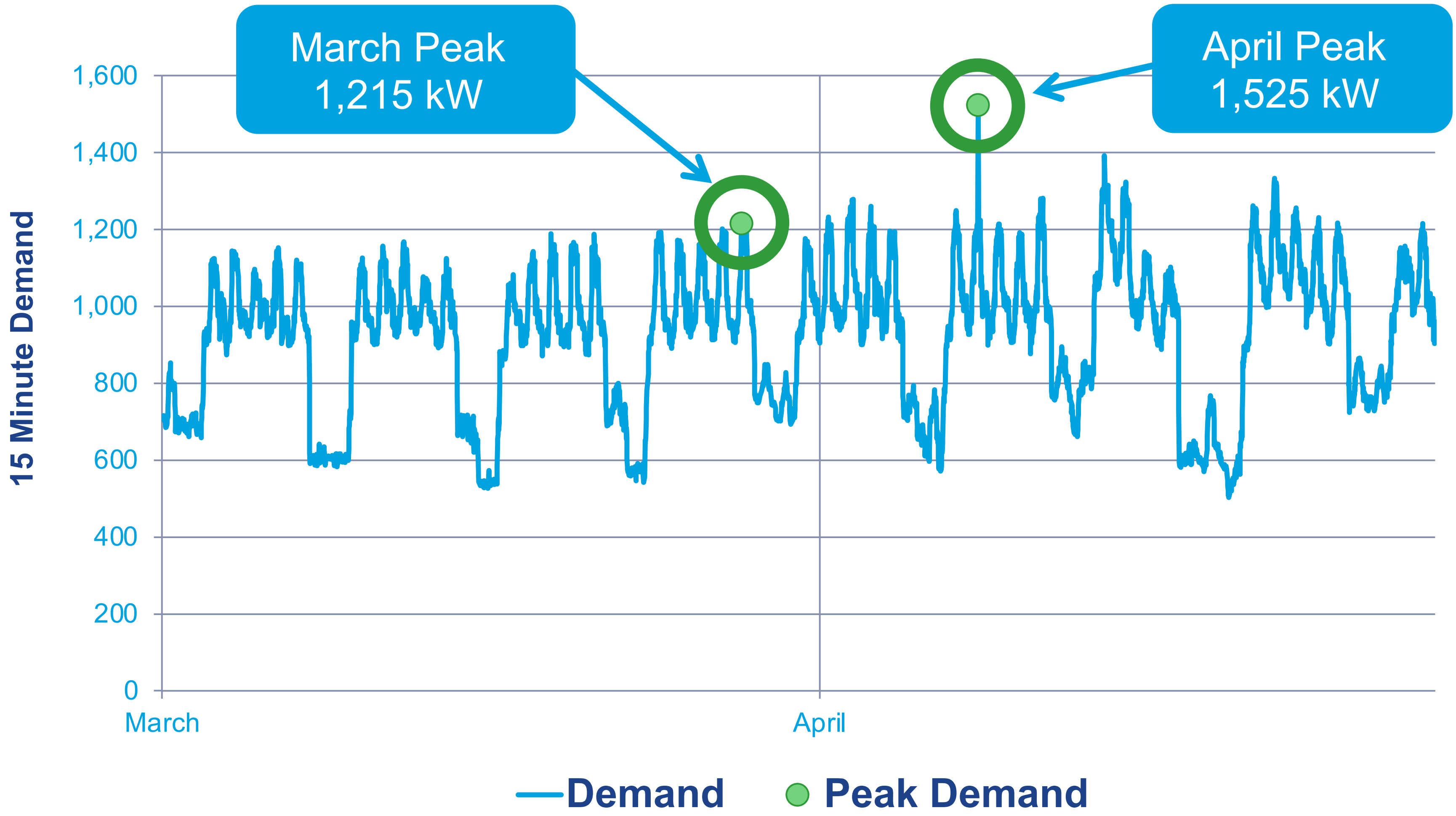
Energy Basics — Peak Demand

GENERATION

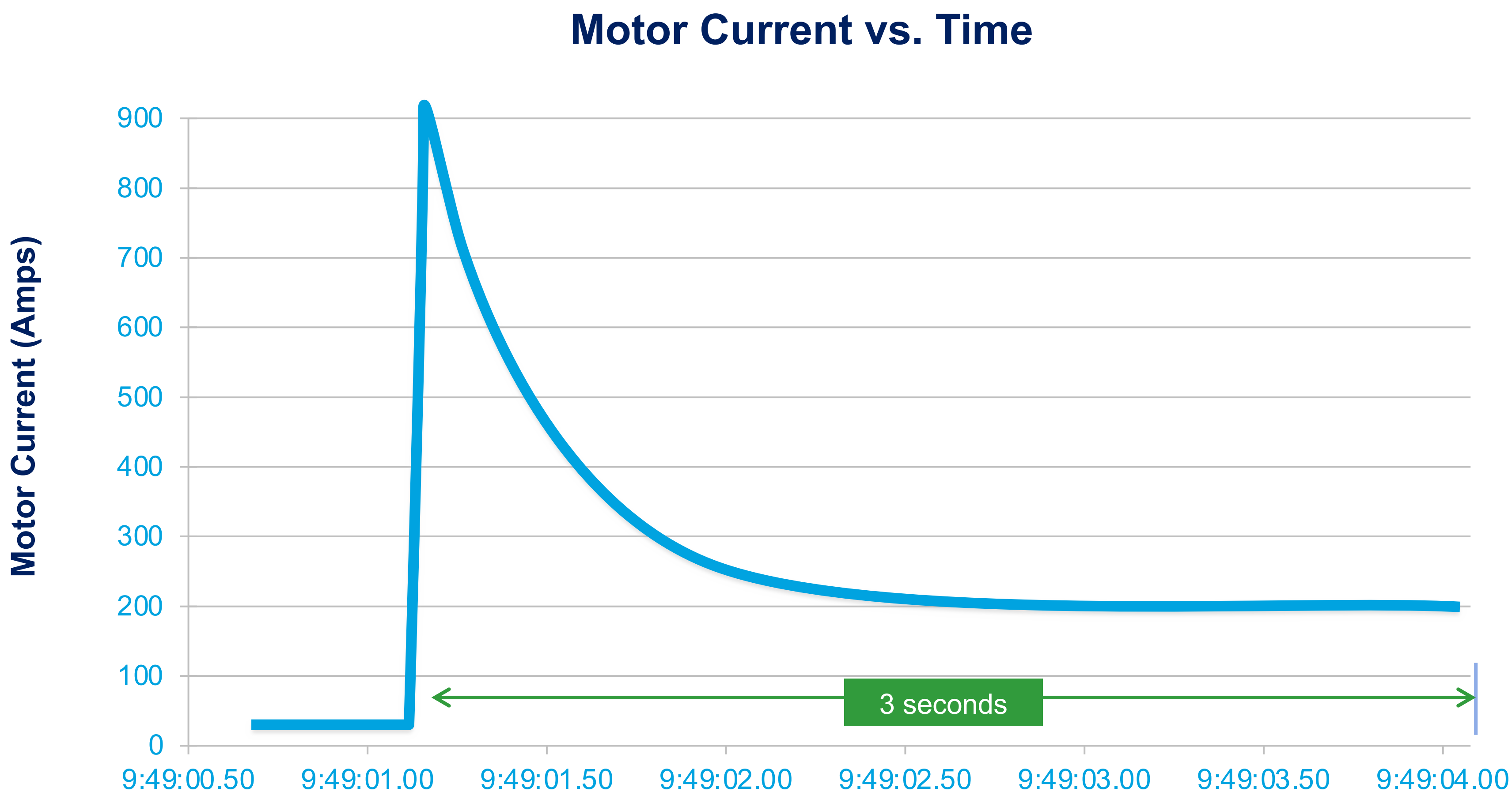
TRANSMISSION

DISTRIBUTION

Peak Demand Example



Motor Inrush Current — Concern or Not?



Session 4

Bacterial Energetics and Aeration

What DO setpoint (mg/l) are you running in your aeration basin?

a. 0 – 1
b. 1 - 2
c. 2 - 3
d. 3 – 4
e. > 4
f. It depends on where in the basin

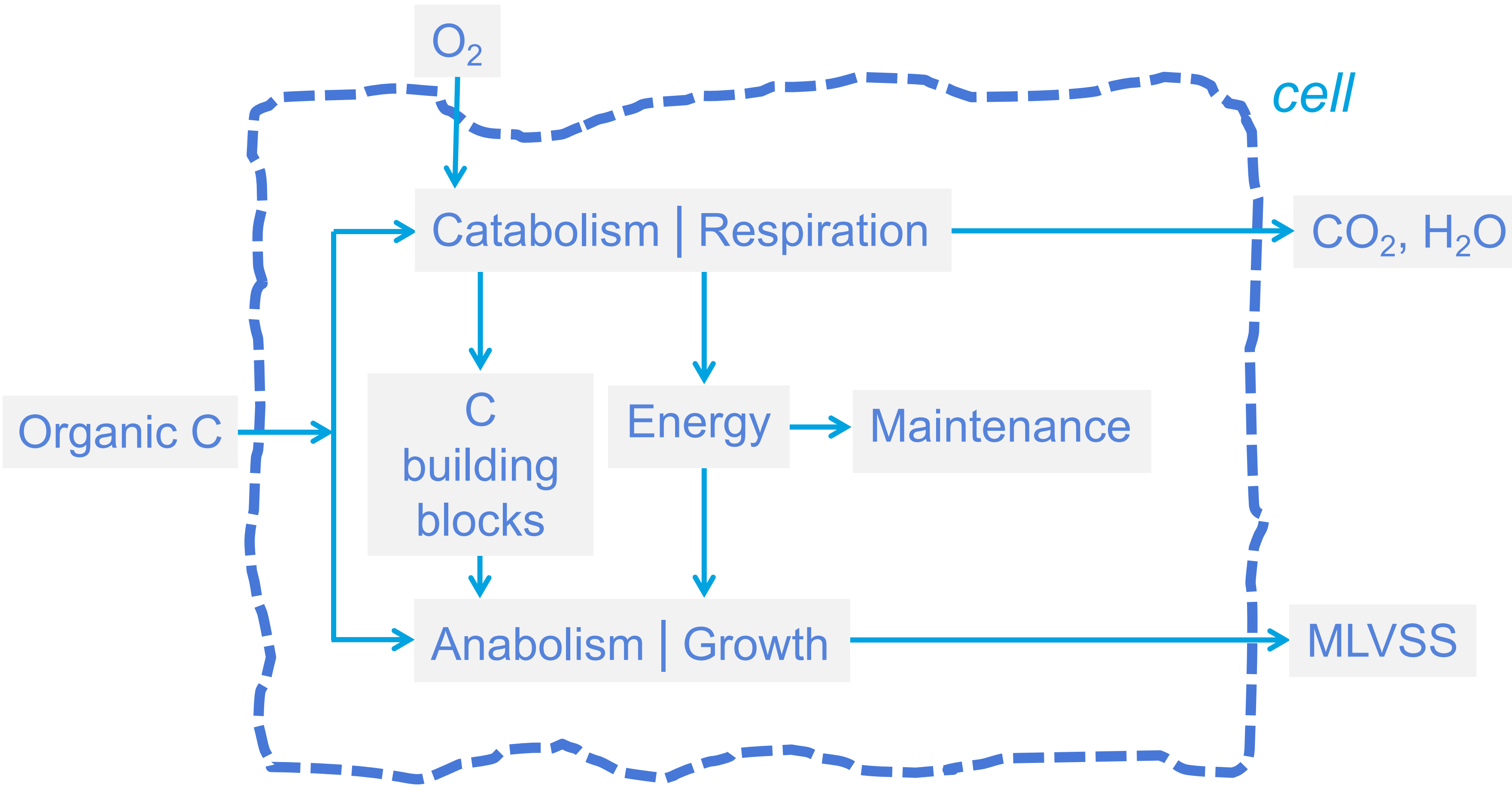
Four Requirements of Life to Live and Thrive

1	Carbon
2	Energy
3	Inorganic nutrients
4	Reducing power

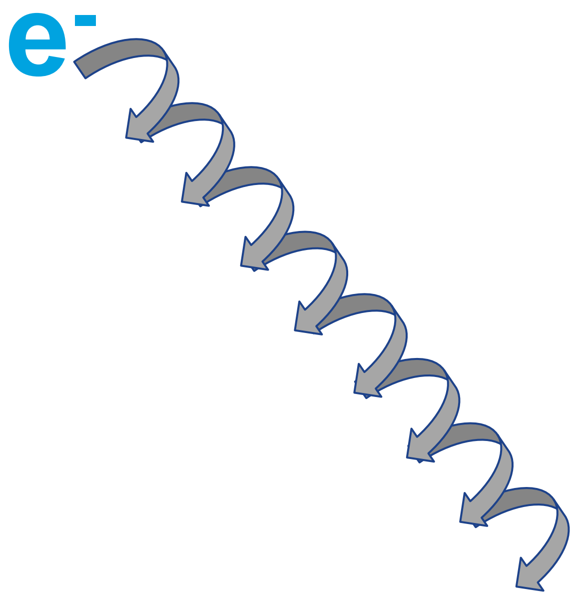
Heterotrophs Get Carbon and Energy From Organic Carbon (Like Us)

1. Carbon
2. Energy
3. Inorganic nutrients
4. Reducing power

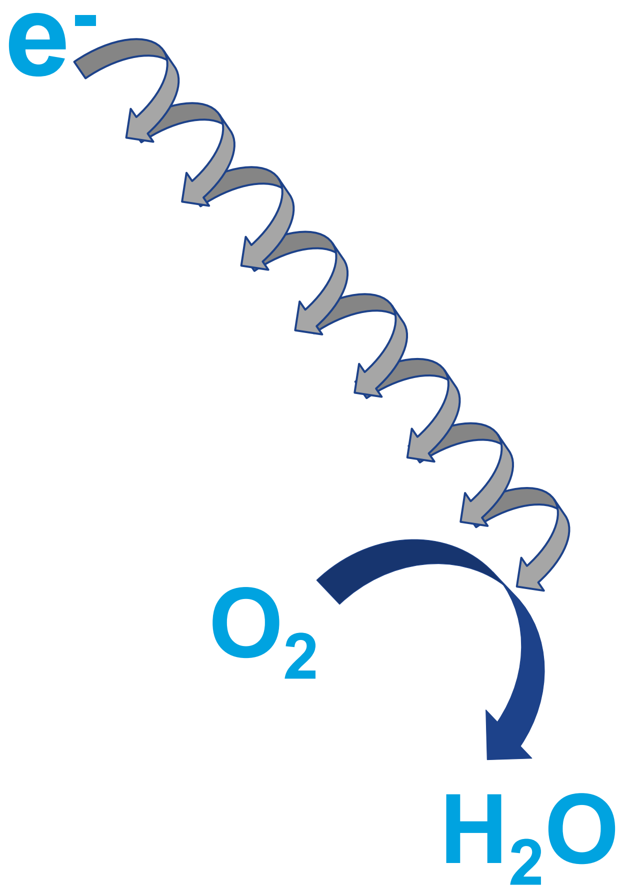
Heterotrophic Metabolism: Catabolism and Anabolism, Energy and Growth



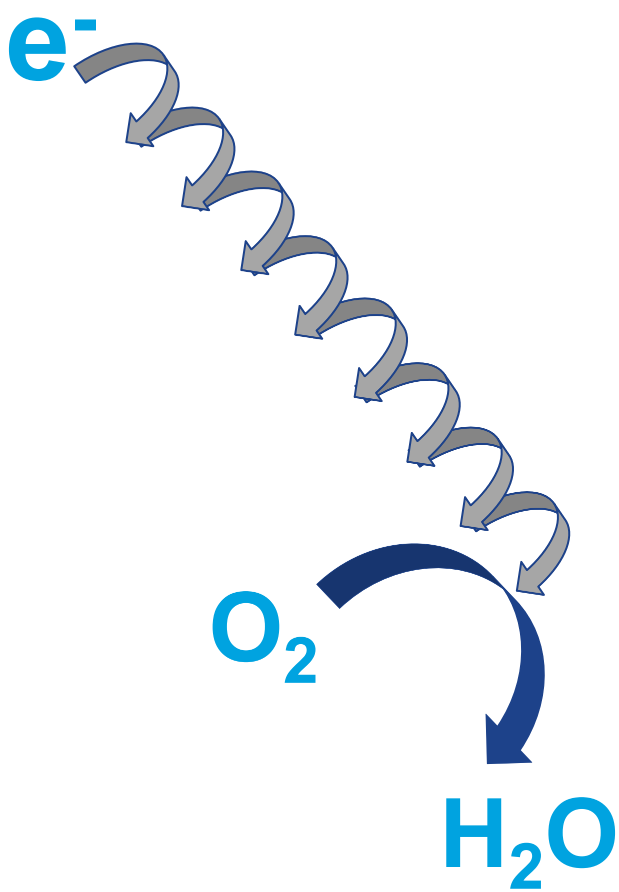
Electron Transport Chains in Cell Membranes Extract Energy



O_2 Serves as the *Terminal Electron Acceptor* in Aerobic Respiration

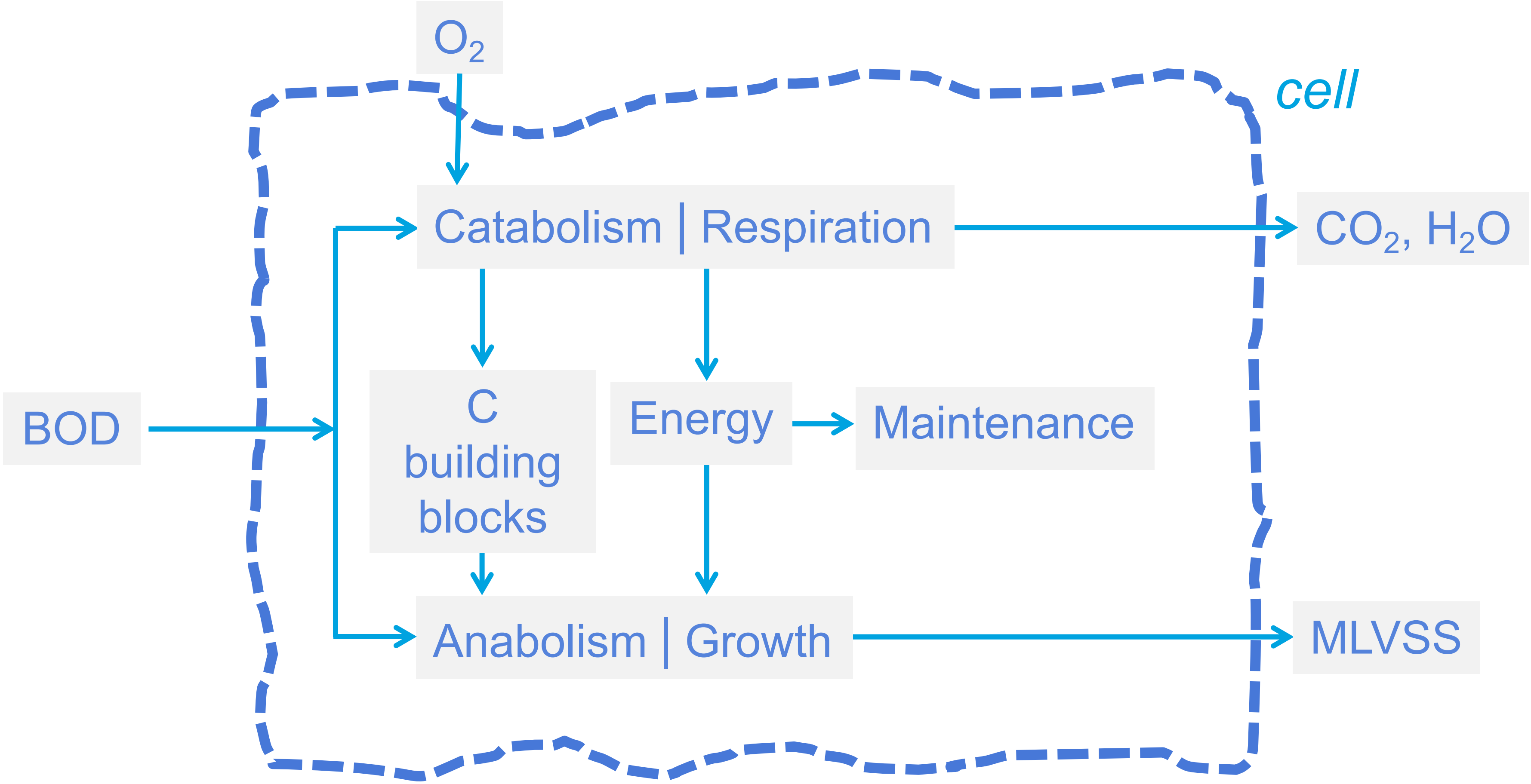


When an Atom Gains Electrons, it is Reduced

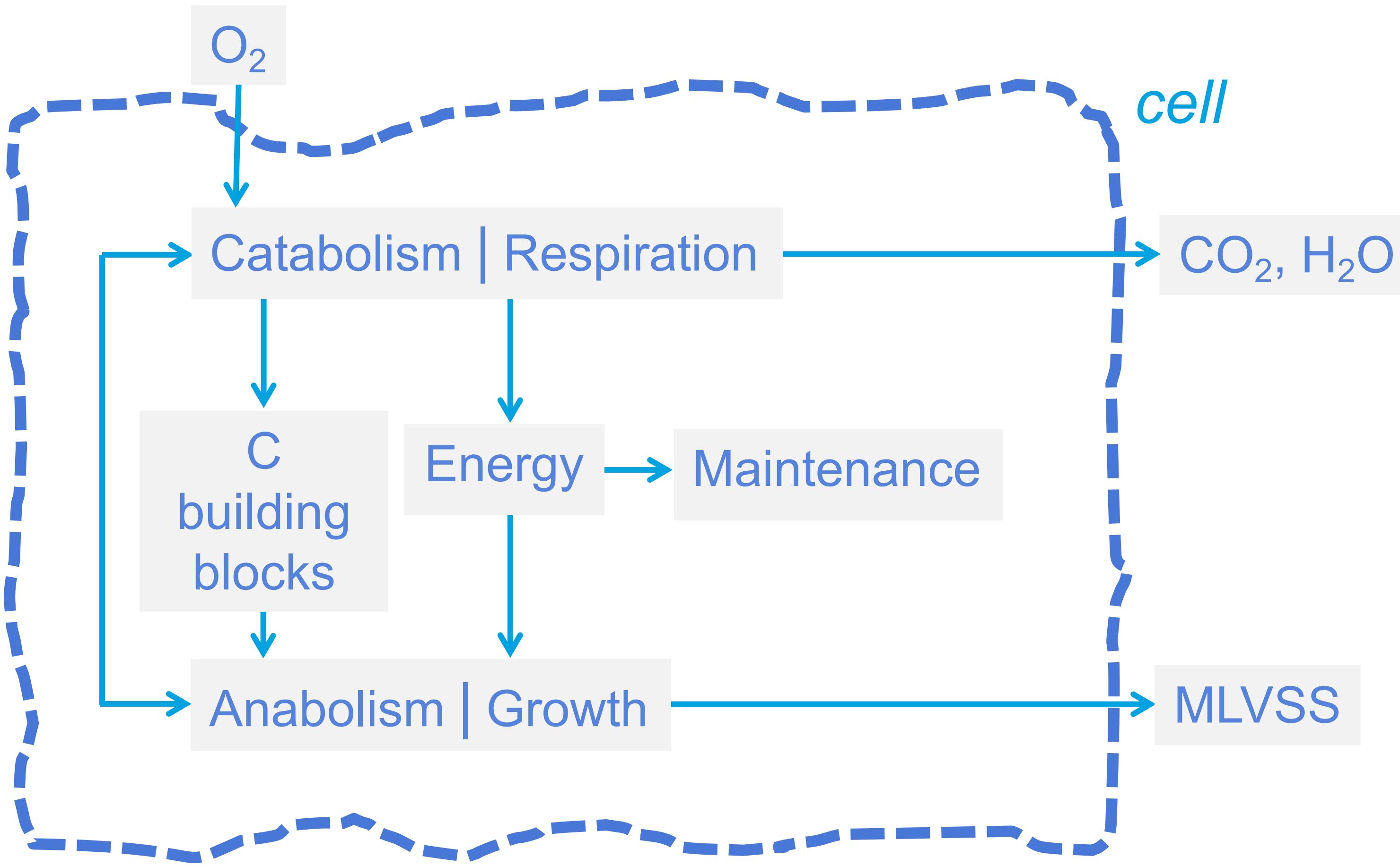


Oxygen is reduced

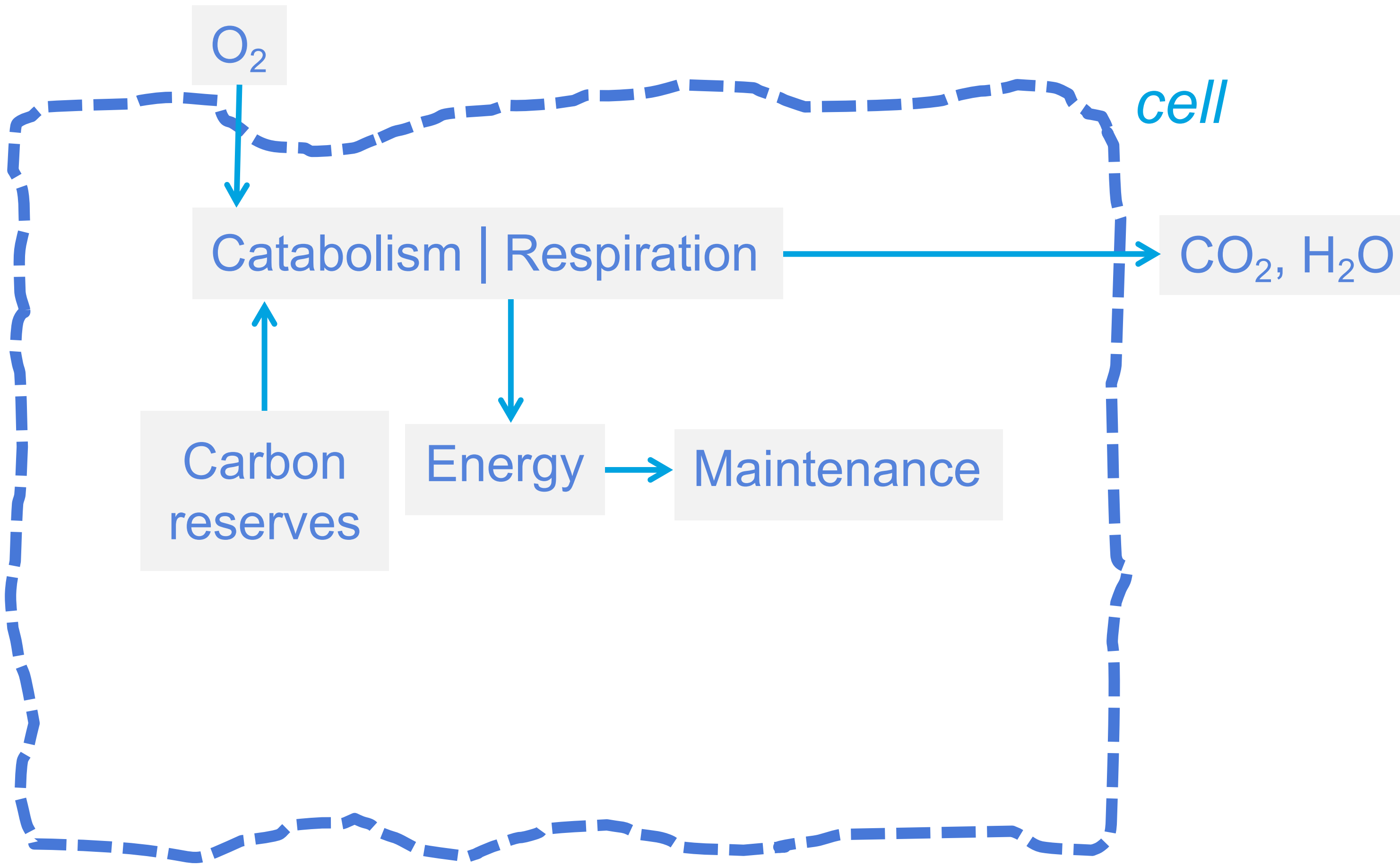
BOD Decreases Until Gone (That's the Goal) What Happens Then?



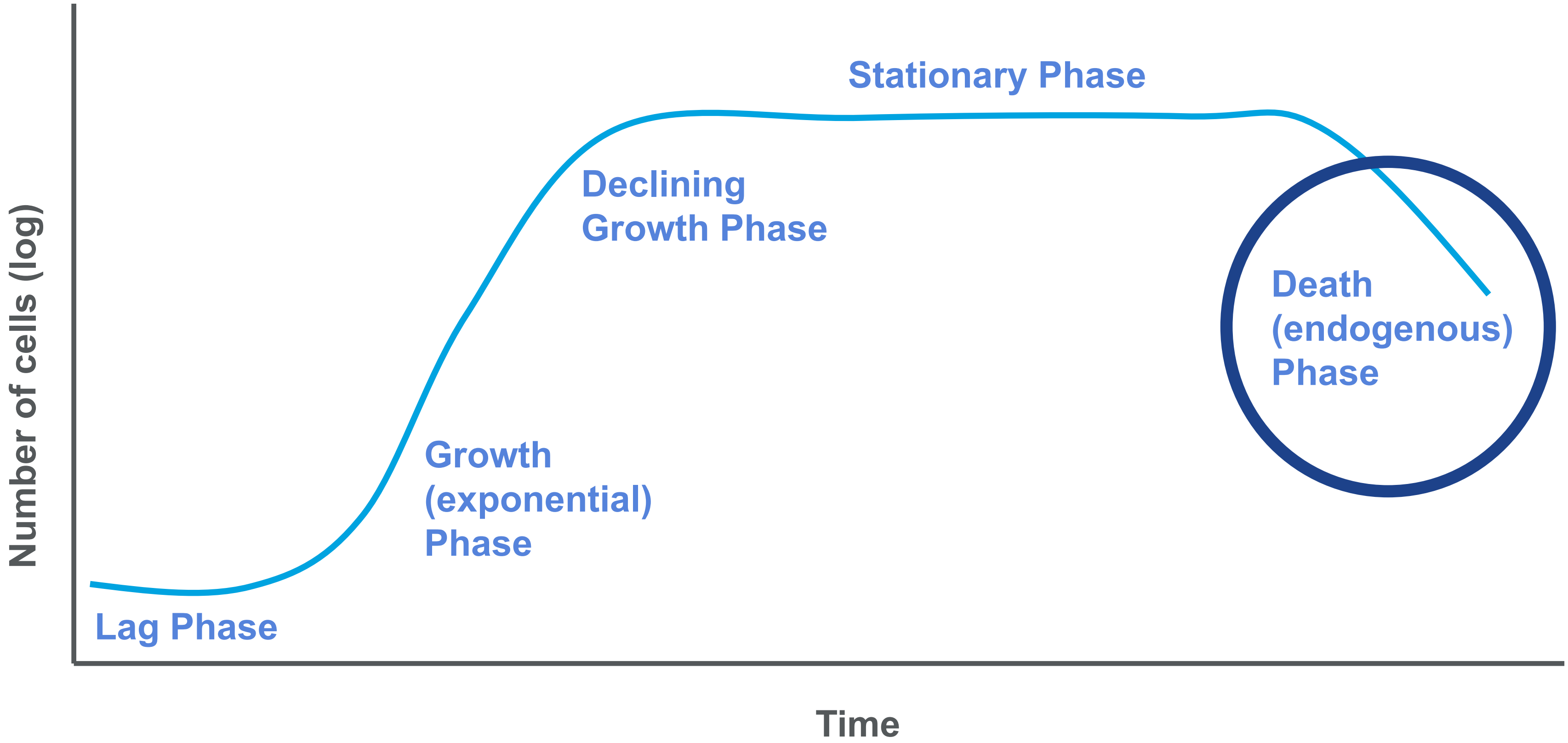
Anabolic Metabolism Shuts Down
Energy Still Needed to Maintain Cell Integrity



Endogenous Respiration Begins When the Cell Starts Using its Own Carbon Reserves

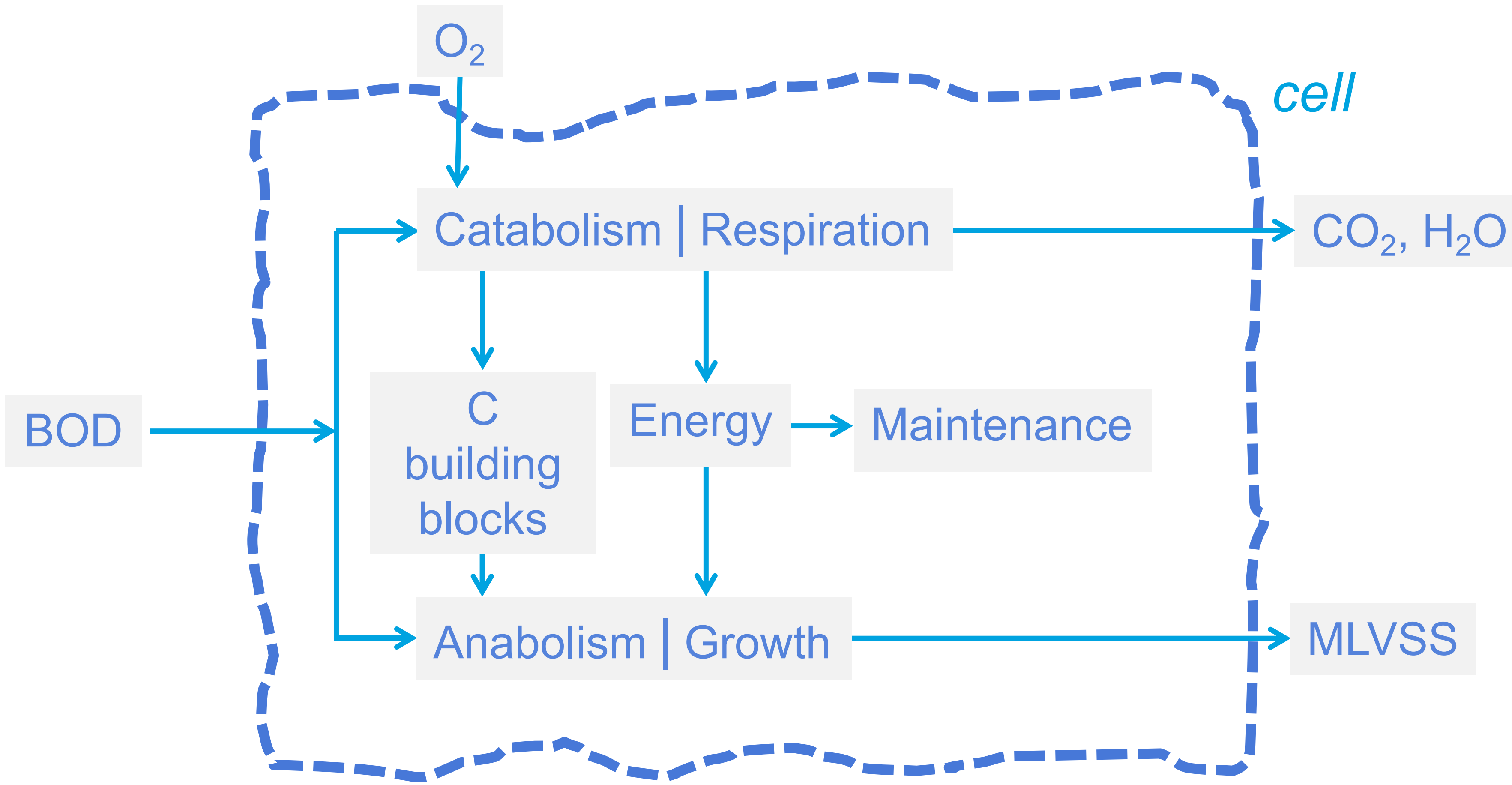


This Graphic is Wrong: Death and Endogenous are Not Synonymous

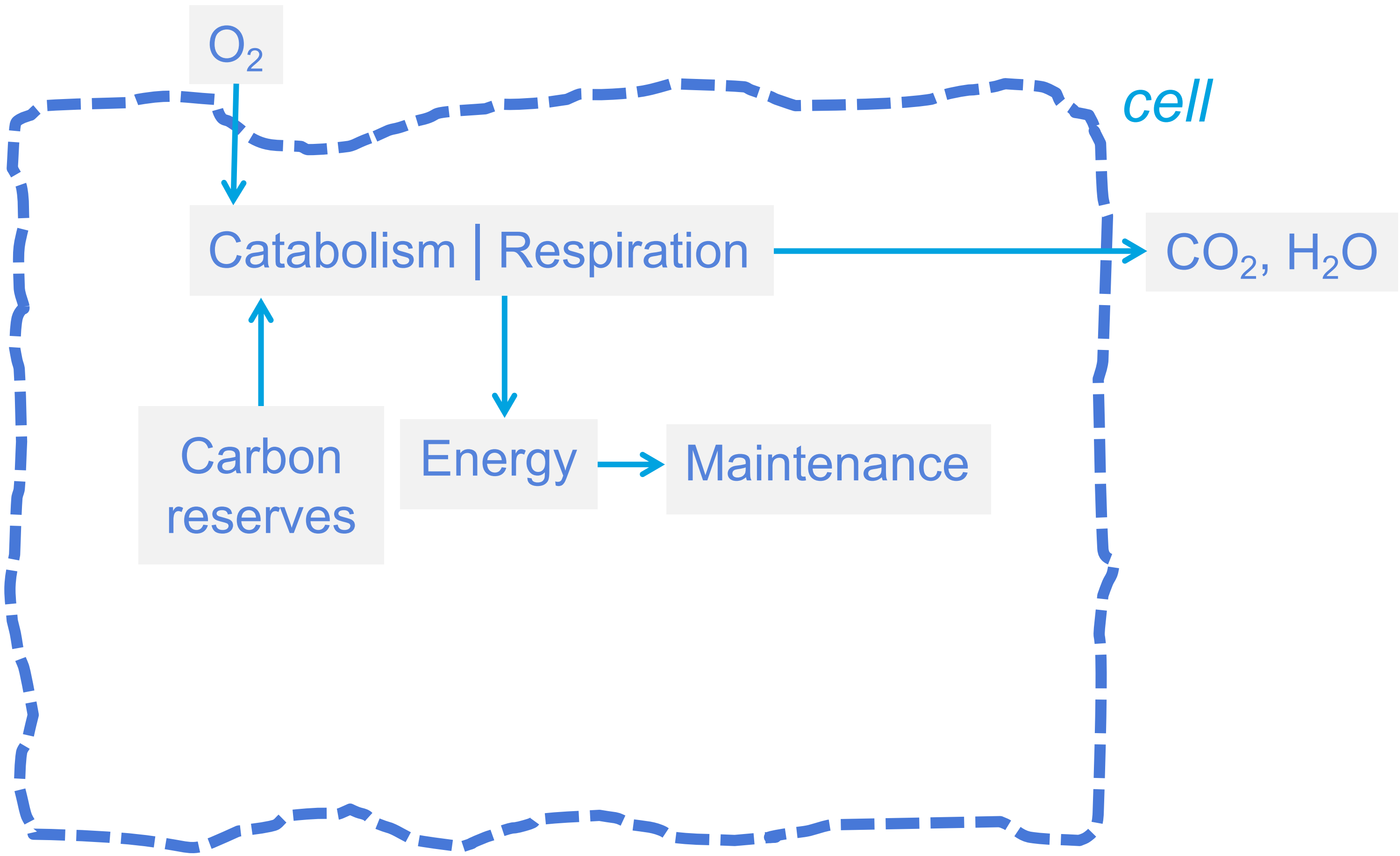


Bacterial Growth Curve
from Auralene Glymph

When the BOD is Gone, the Biomass Goes Endogenous; it Does Not Die

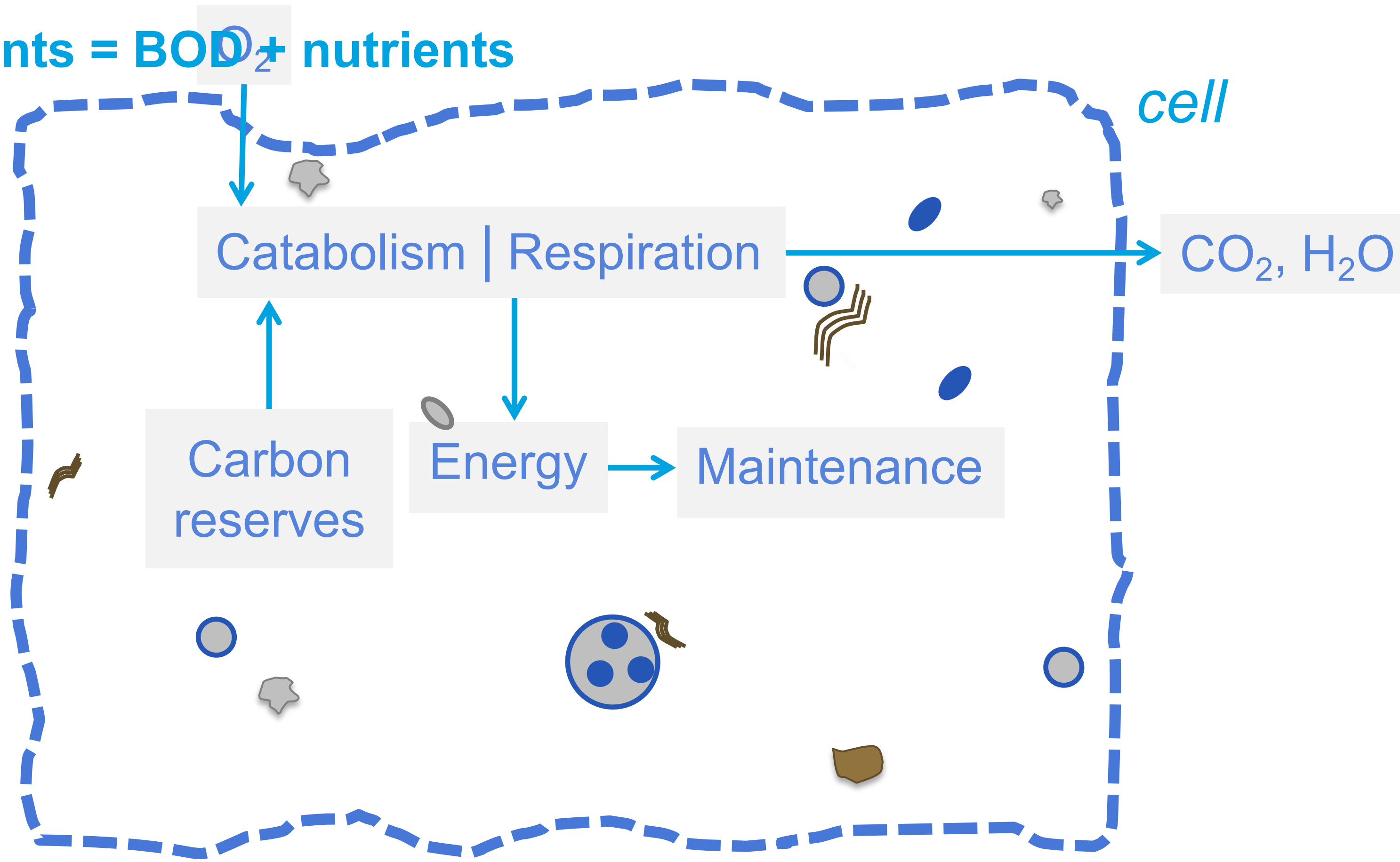


When the BOD is Gone, the Biomass Goes Endogenous; it Does Not Die

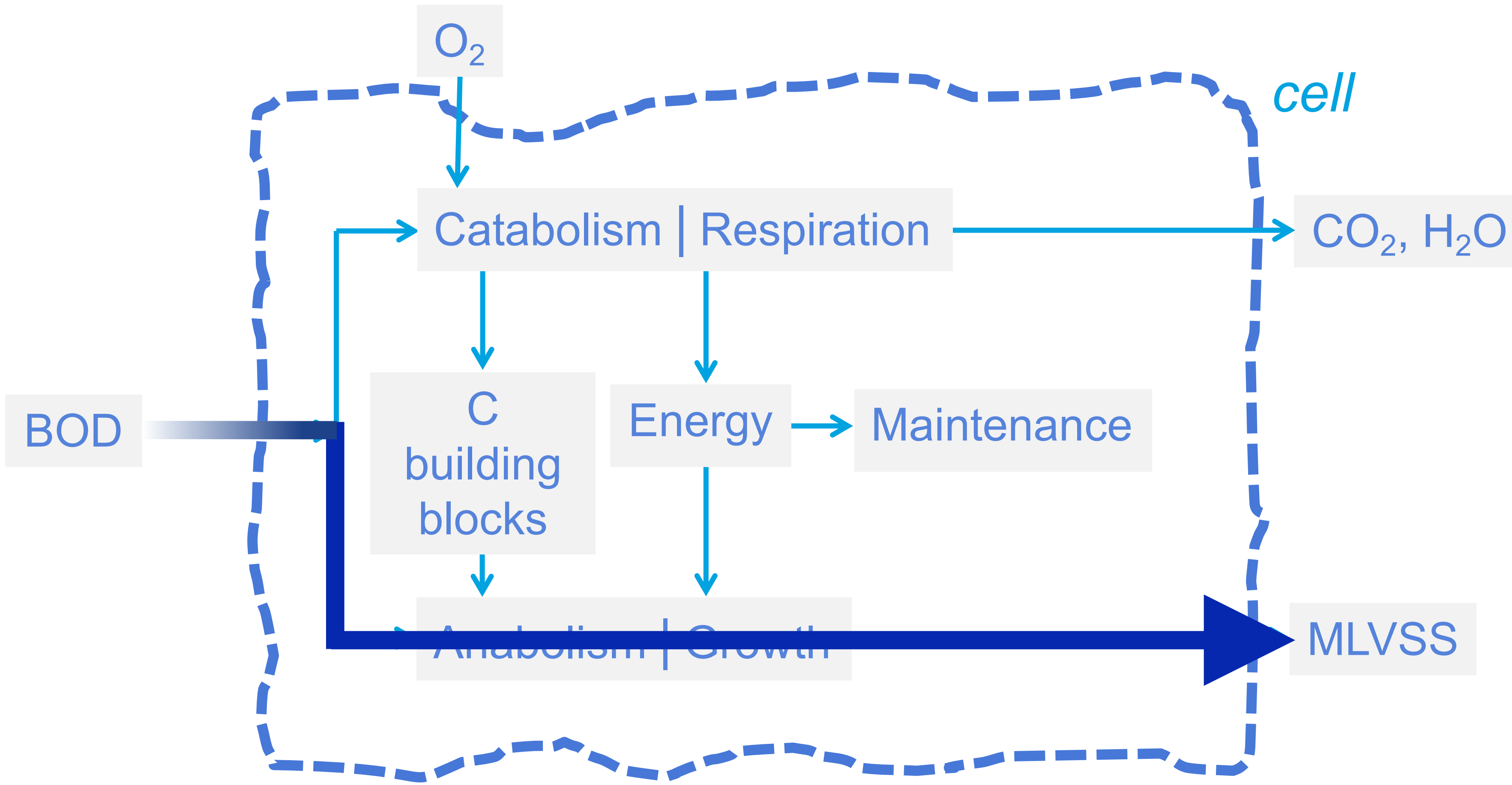


A Different Story When Carbon Reserves Run Out

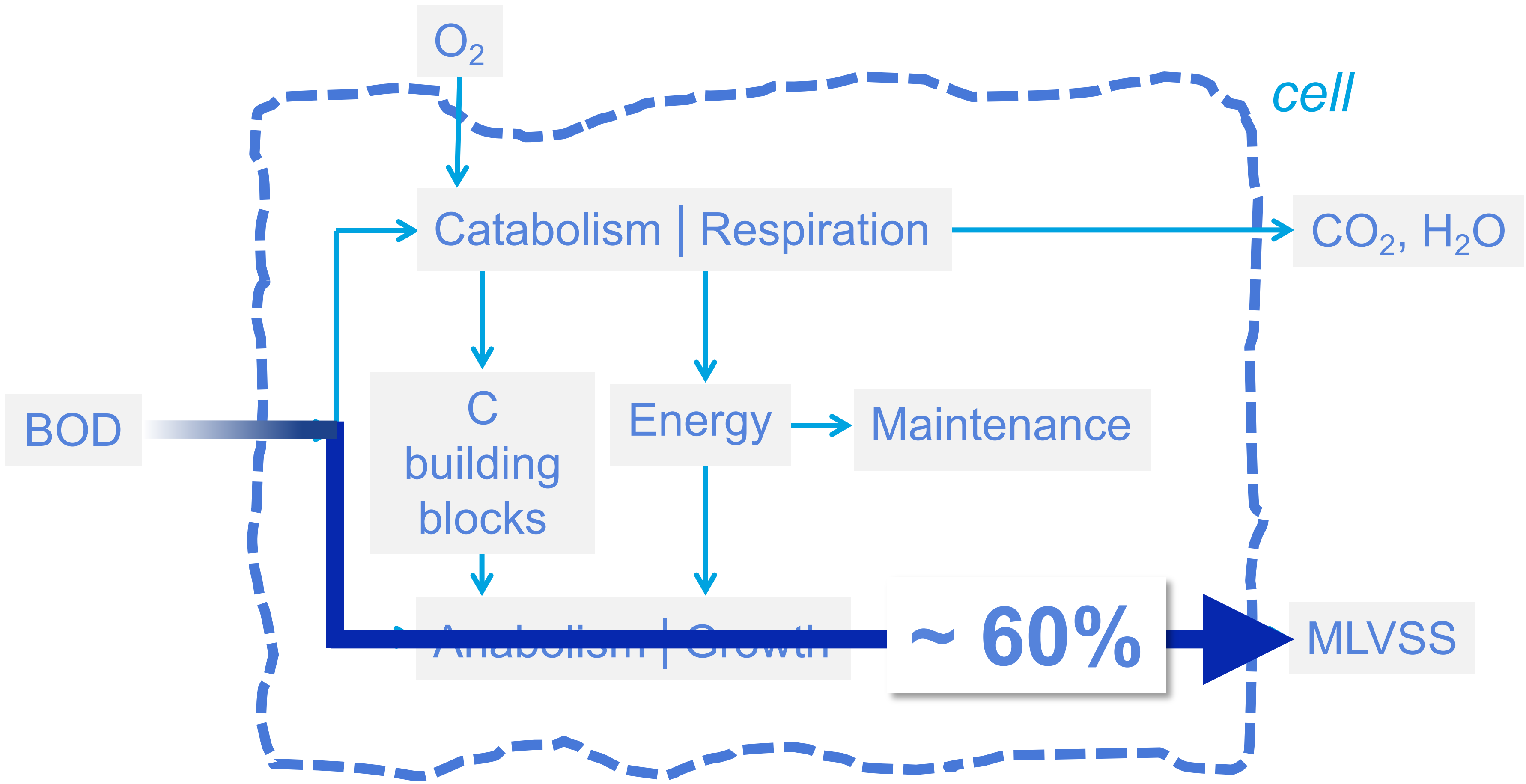
Cell contents = BOD + nutrients



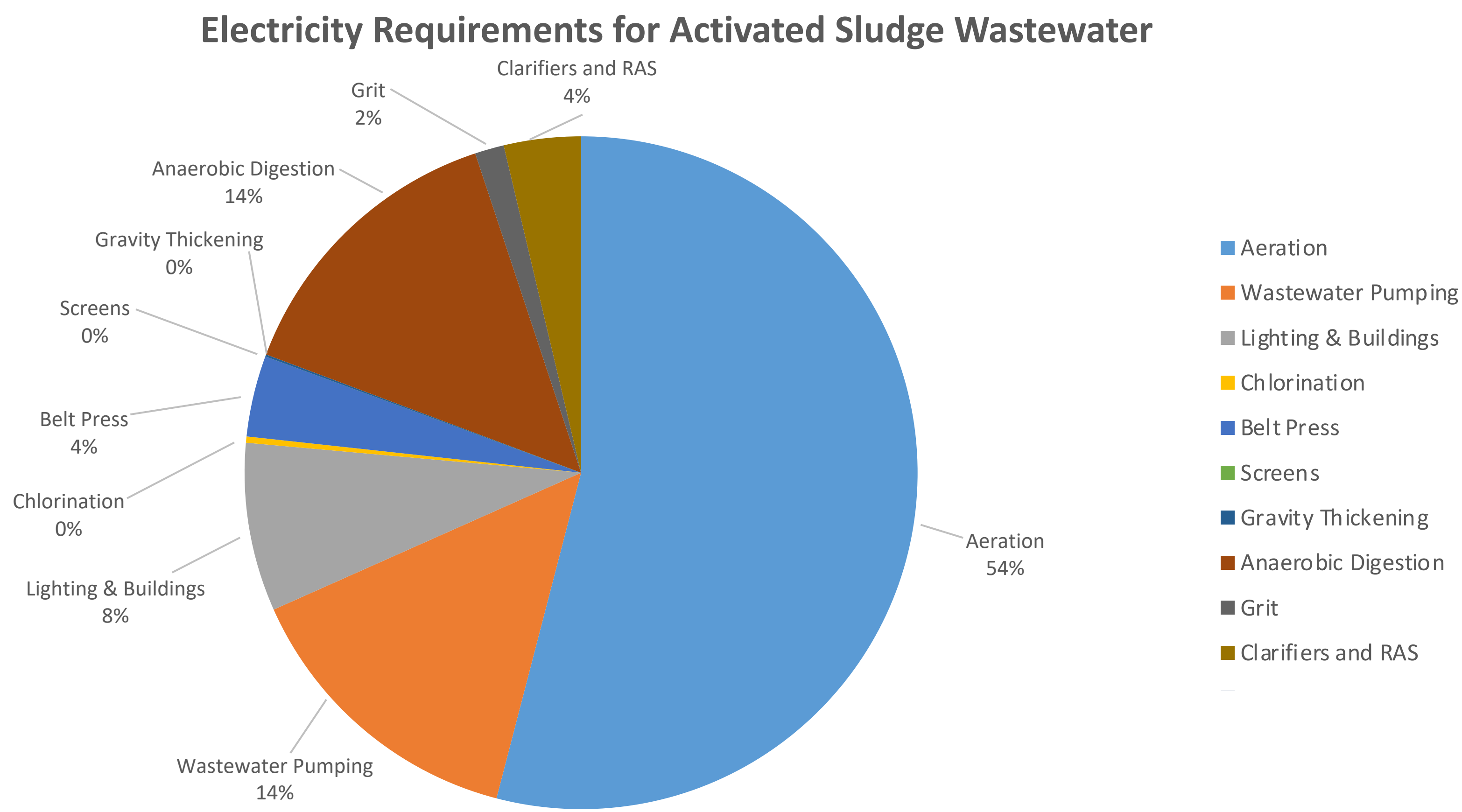
Yield: How Much Influent Organic C (BOD) is Converted to Organic C in New Cells (MLVSS)



More Influent BOD is Converted to New Cells Than Oxidized for Energy (and respired)



Plant Process Electricity Use Overview



Derived from data from Focus On Energy WWOA 49th Annual Conference, October 7, 2015 presentation by Joseph Cantwell, PE

A Gallon of Milk…

Weighs ~8.34 lb

Has a BOD concentration of approximately 120,000 mg/L

How many pounds of BOD?

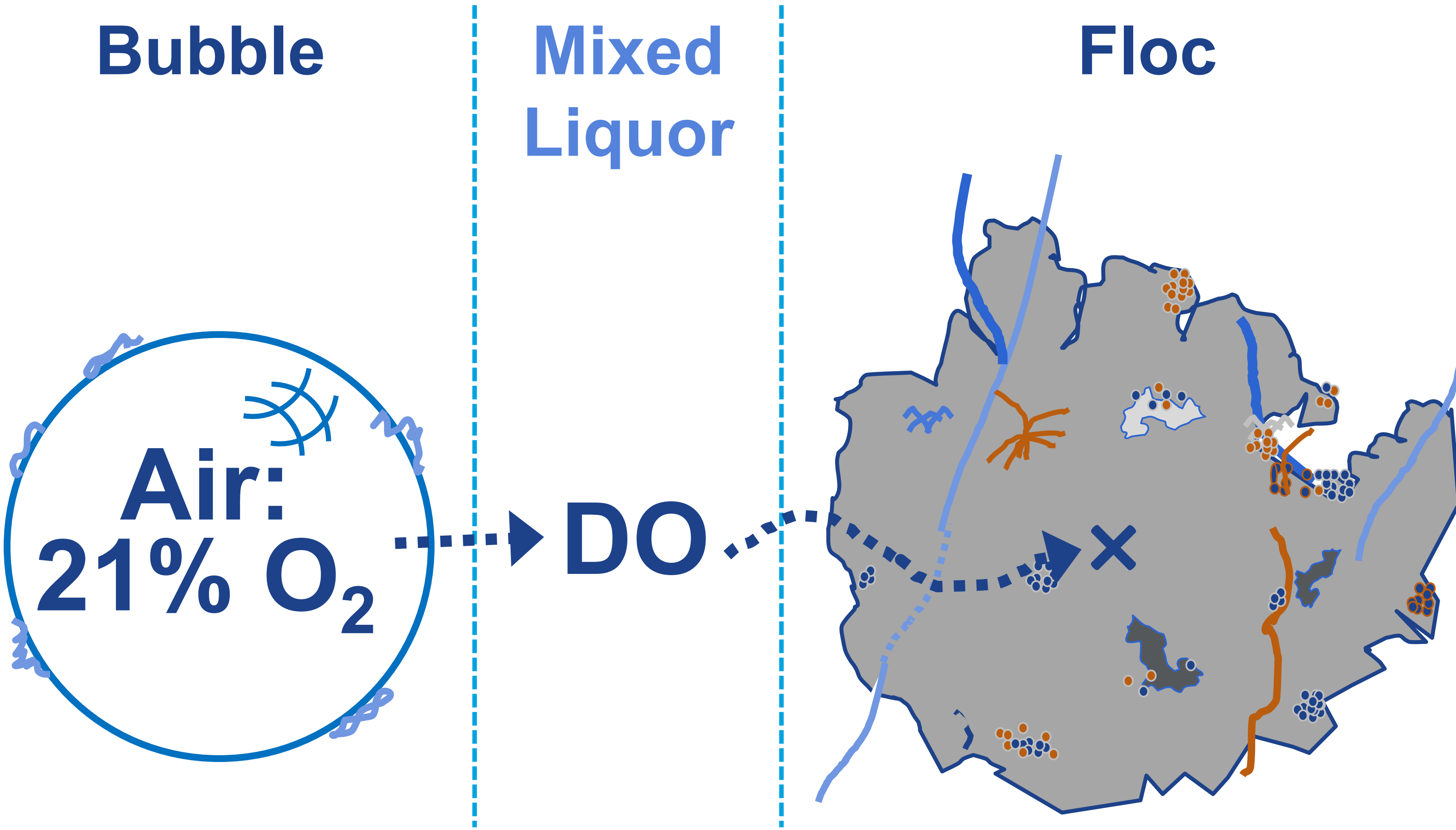
A Gallon of Milk = One Pound of BOD

What does that mean?

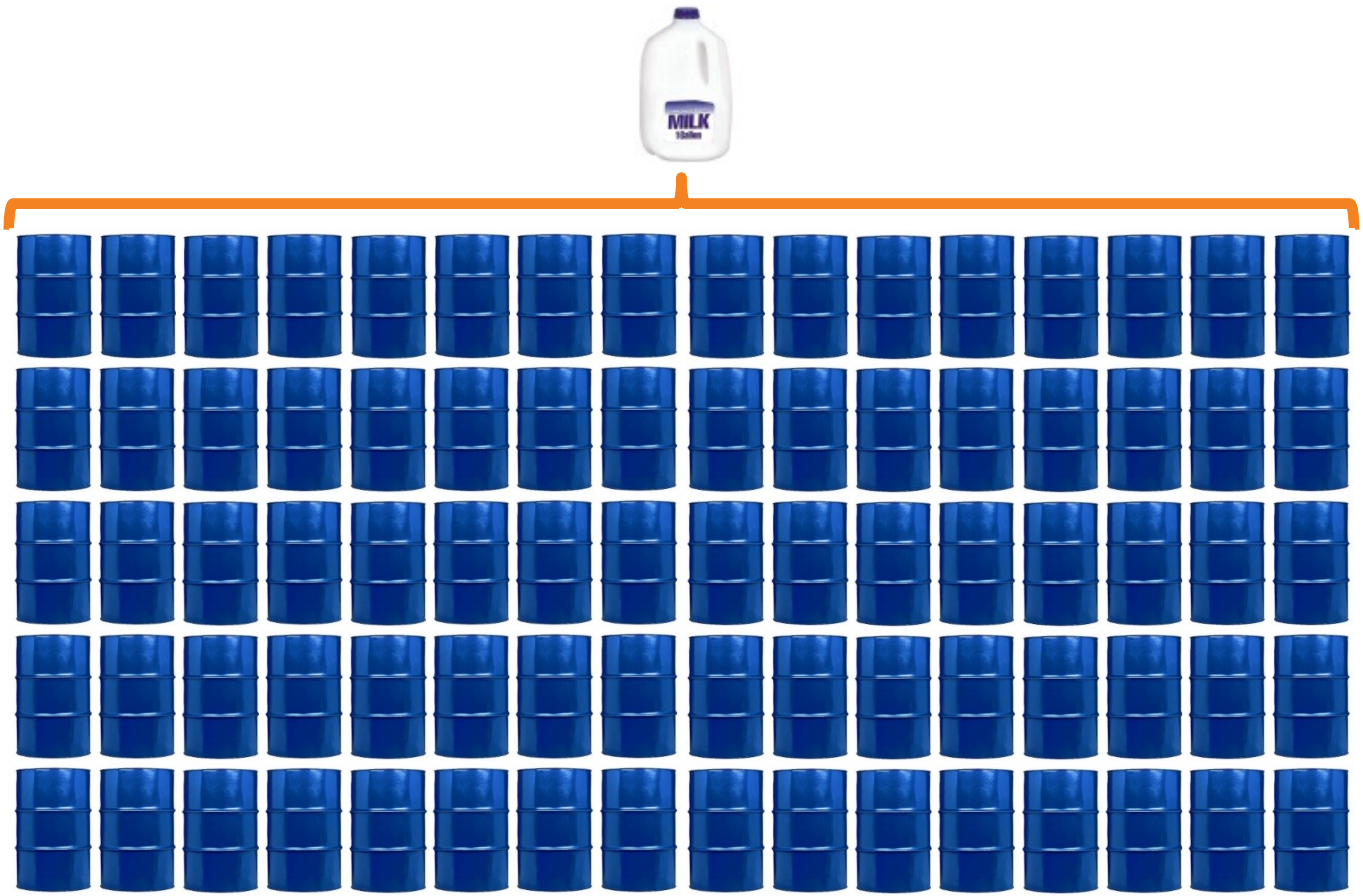
A Pound of Oxygen From the Atmosphere…

~Eight 55-gallon drums of air

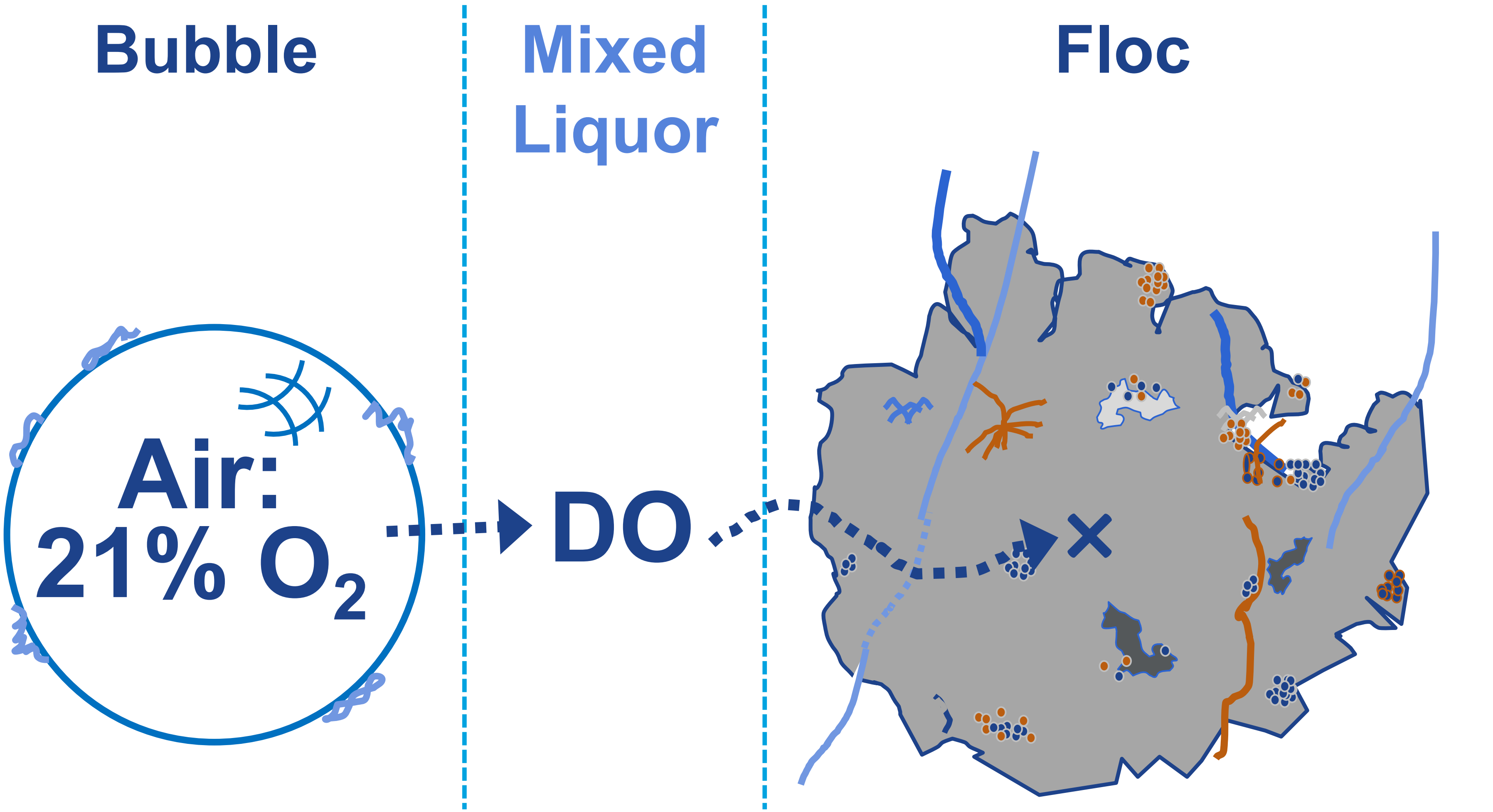
The Reason so Much Aeration is Required. . . .



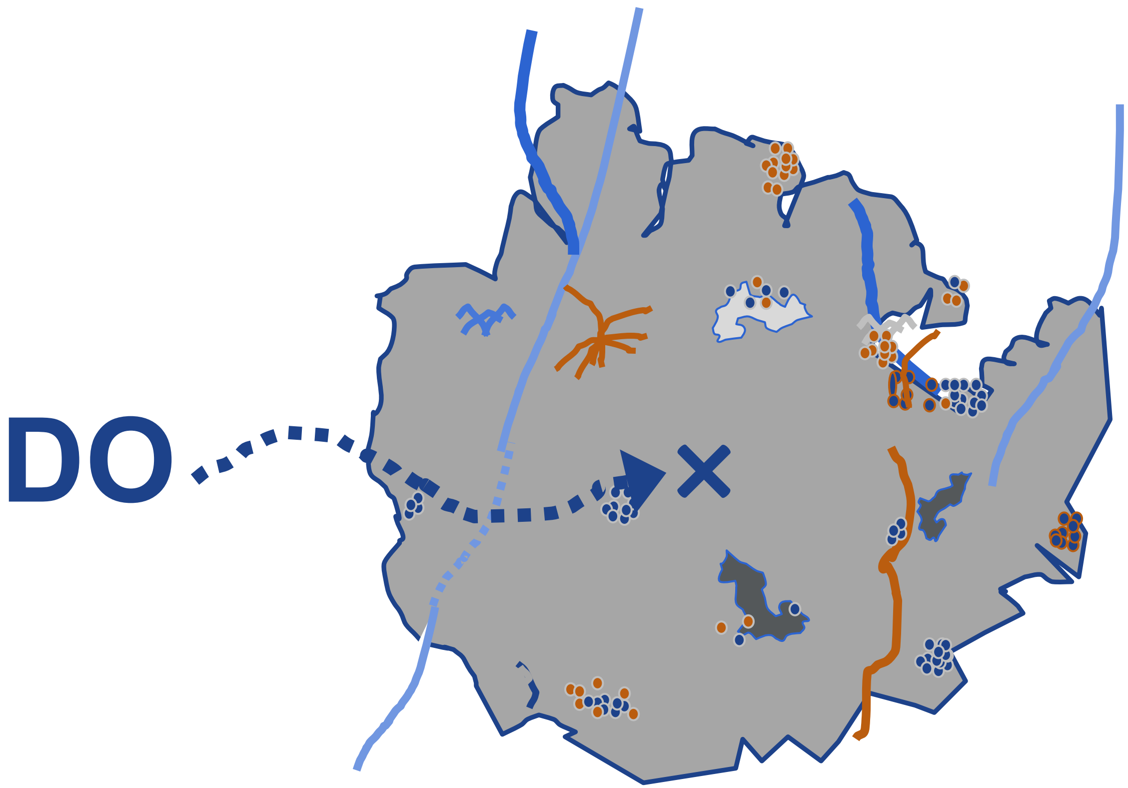
Eighty 55-Gallon Drums of Air



Mixed Liquor DO Concentration Must Be High Enough to Accomplish Two Things

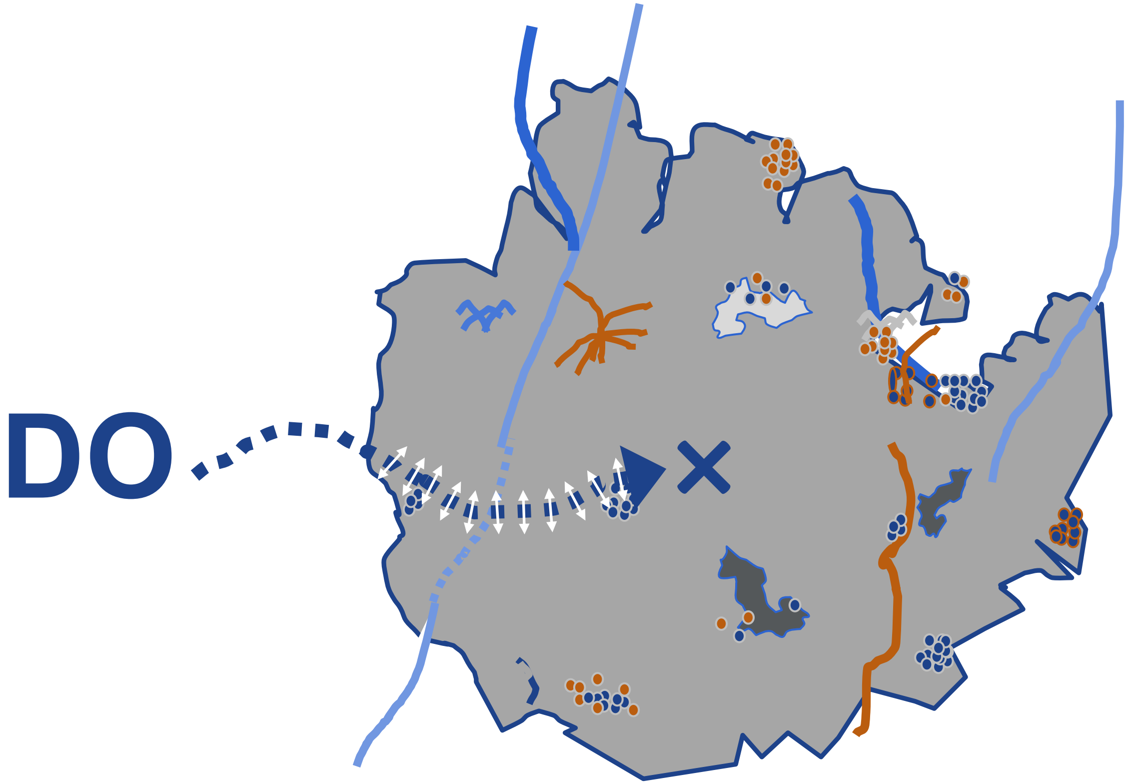


1. Must Provide Sufficient Gradient to Diffuse Oxygen Into Floc Center



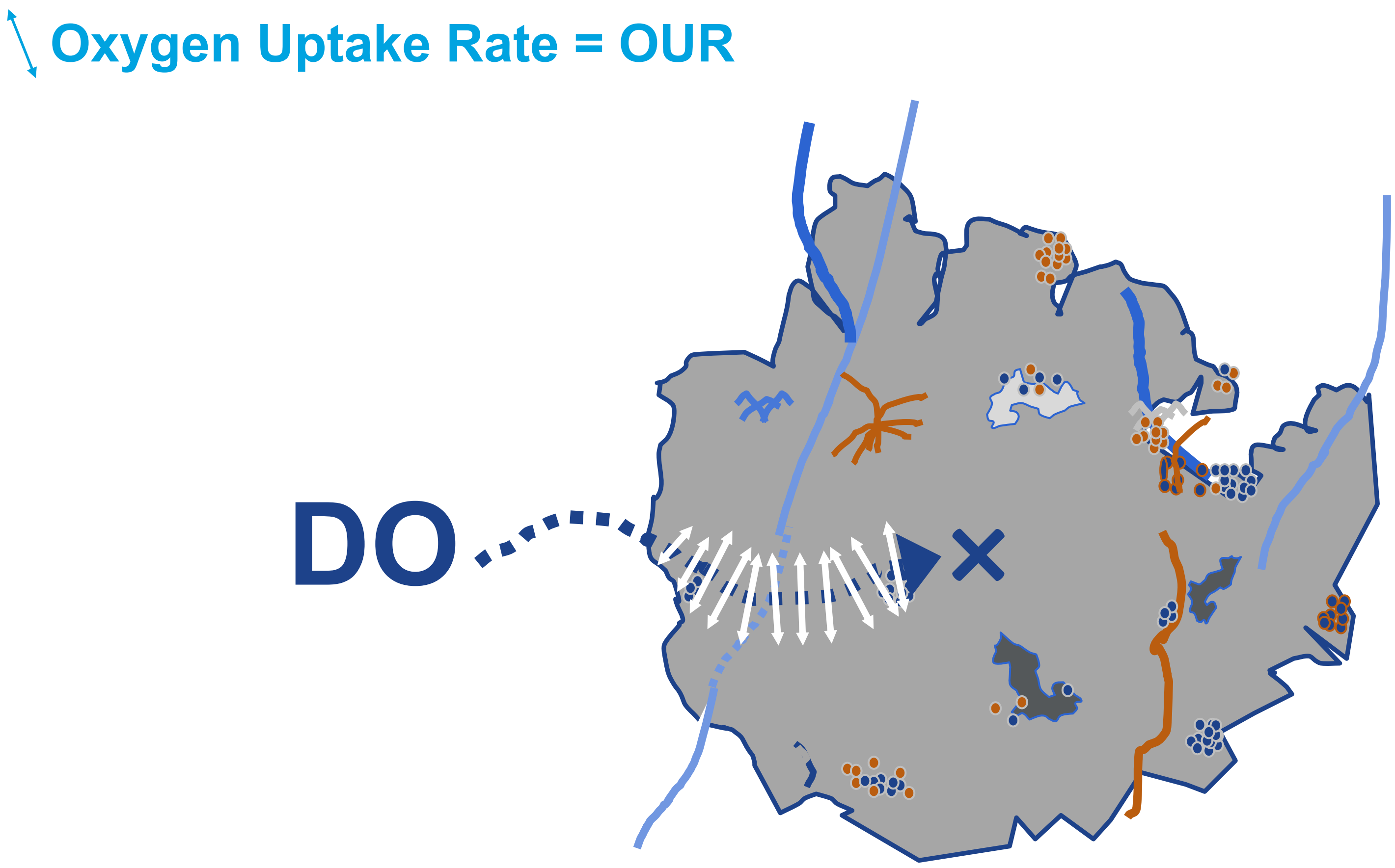
2. While Oxygen is Being Continuously Consumed for Aerobic Respiration

Oxygen Uptake Rate = OUR

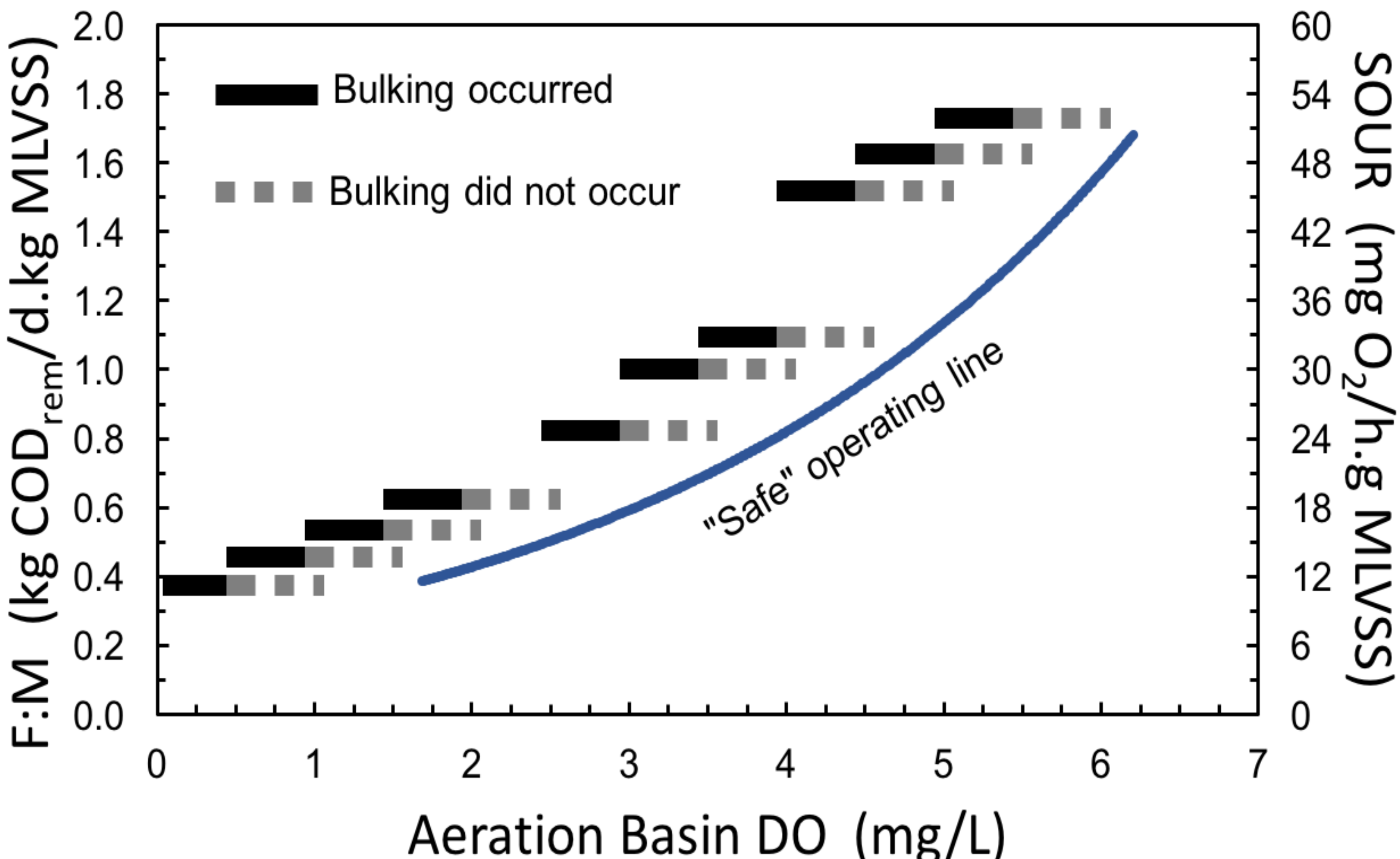


More BOD Results in Greater OUR, Requiring Higher DO Concentration in Mixed Liquor

Oxygen Uptake Rate = OUR

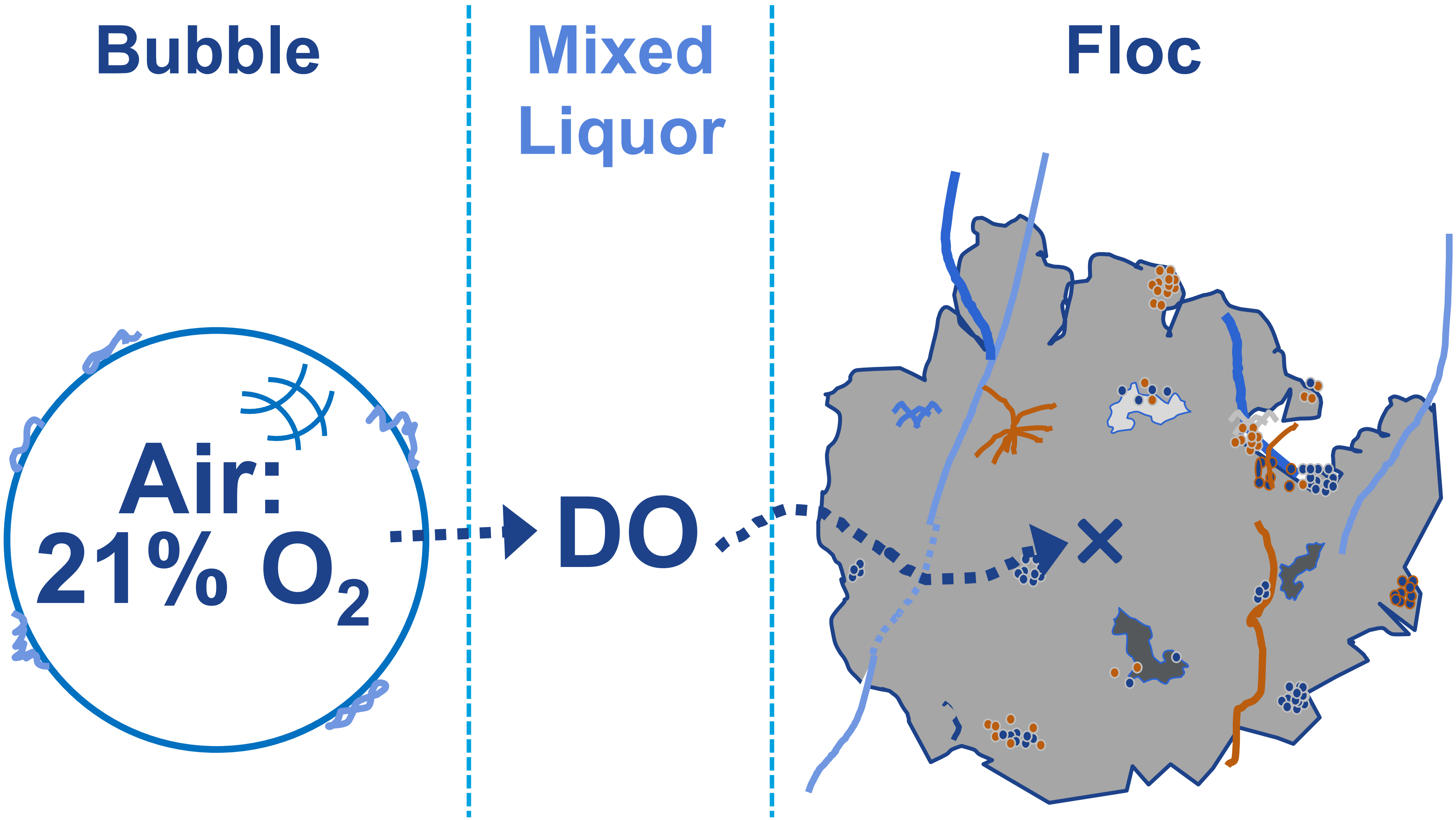


Jon Palm's Ph.D. Work: DO Set Point Depends On Organic Loading and OUR (here SOUR)

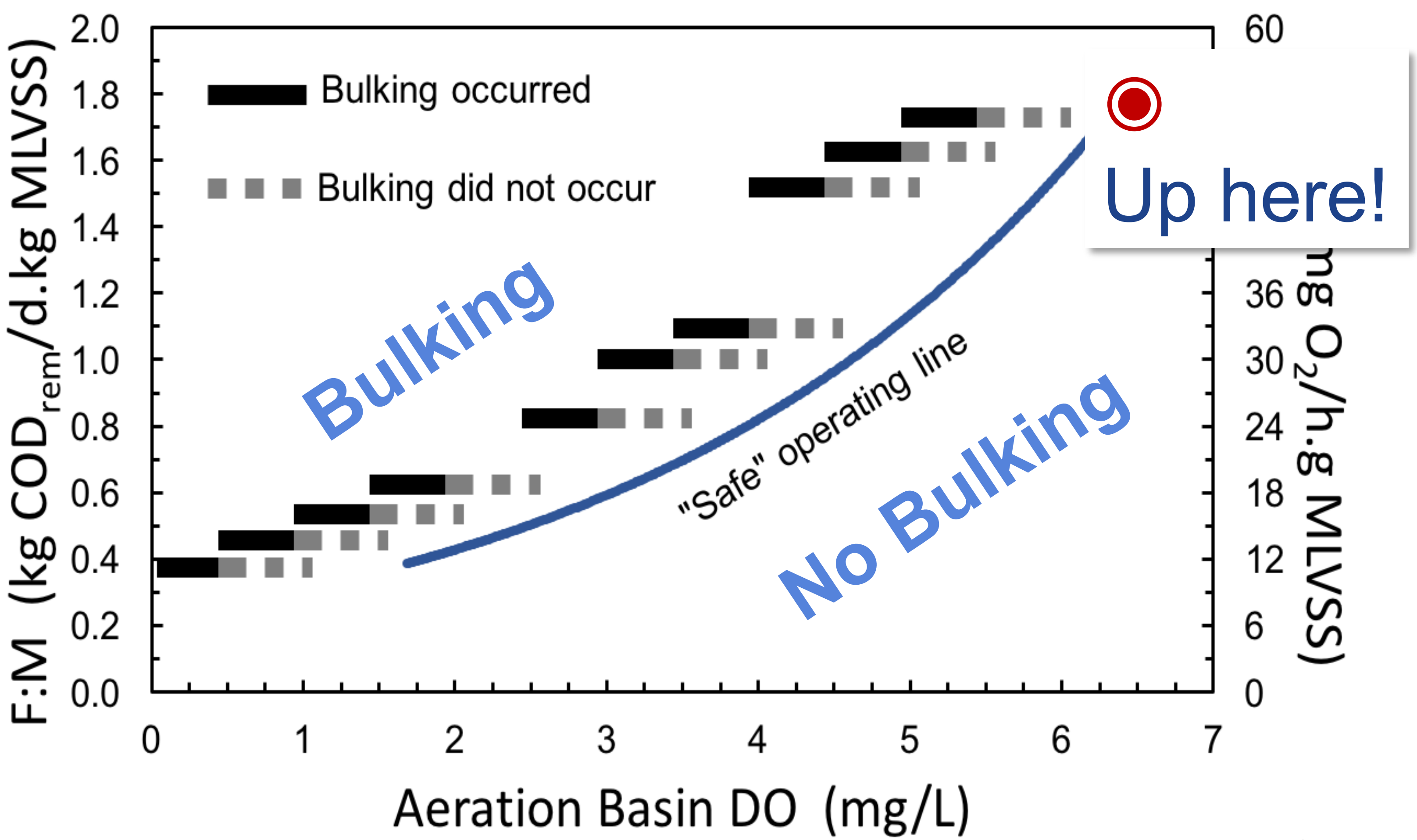


Ph.D. work of Jon Palm

Need High DO Where There's High BOD
Given Enough DO, BOD Goes Fast

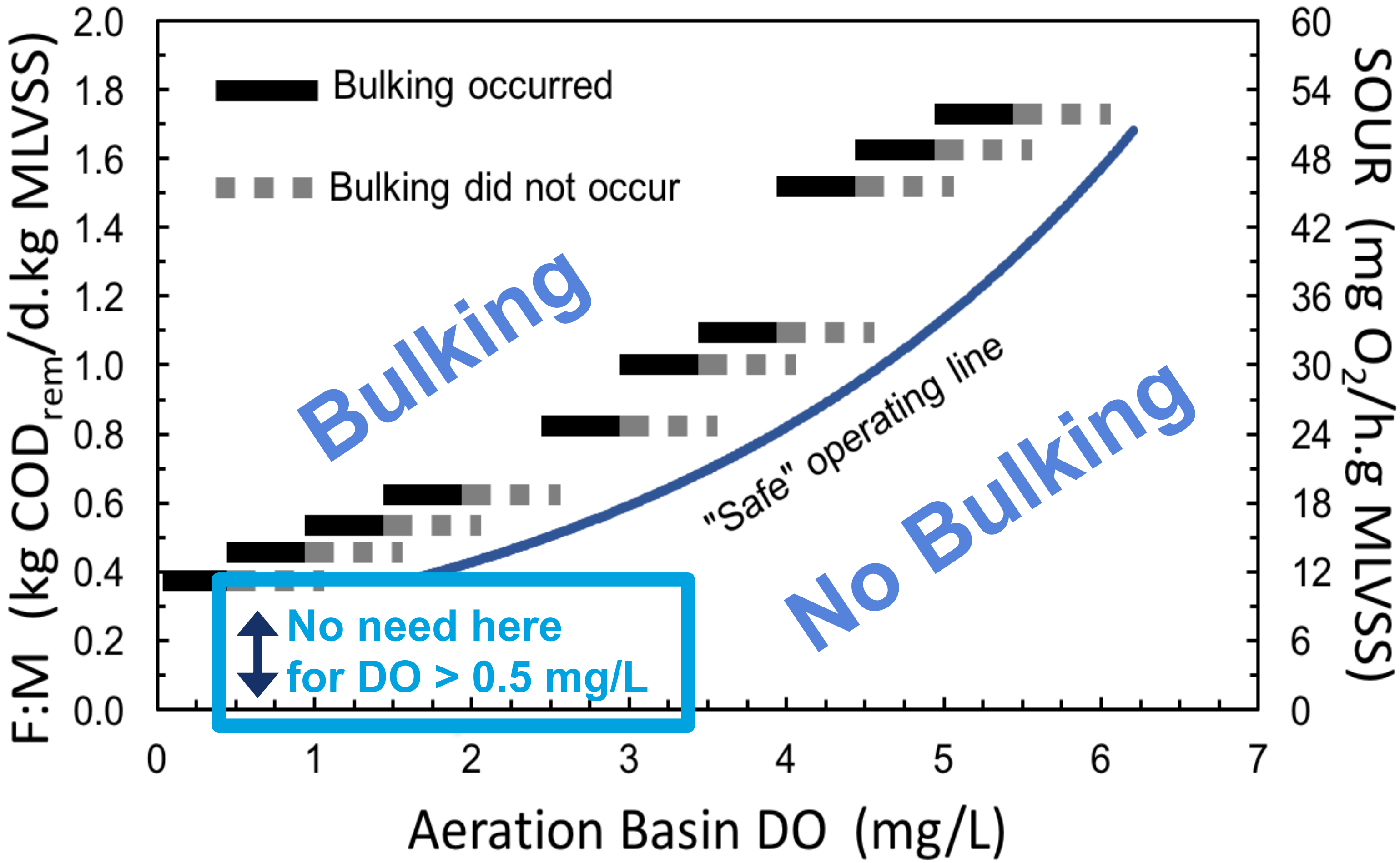


DO Requirement Greatest When Oxygen Uptake Rate is Highest (High BOD)



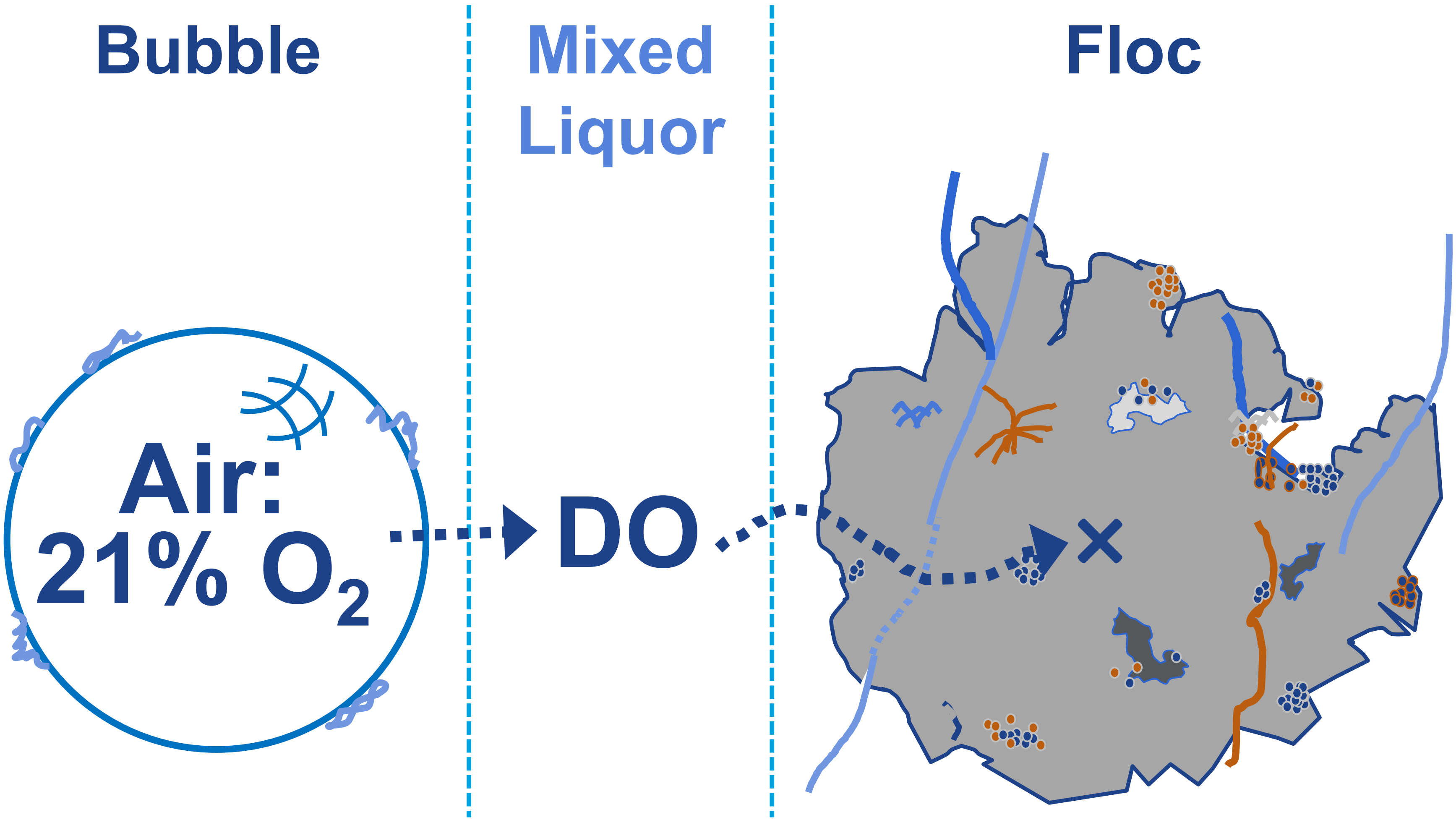
Ph.D. work of Jon Palm

When BOD is Gone, DO Requirement Minimal—Potential for Huge Energy Savings

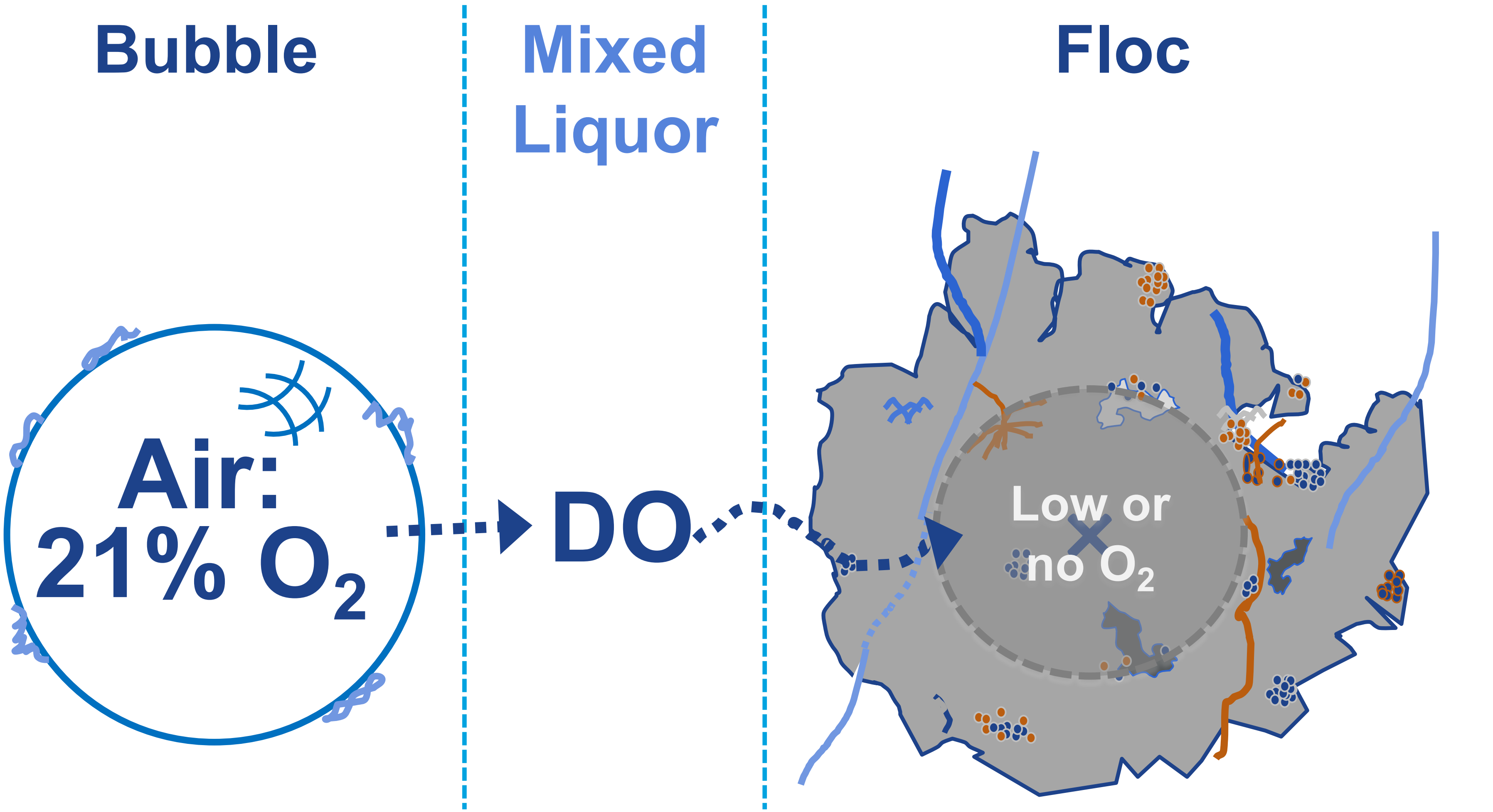


Ph.D. work of Jon Palm

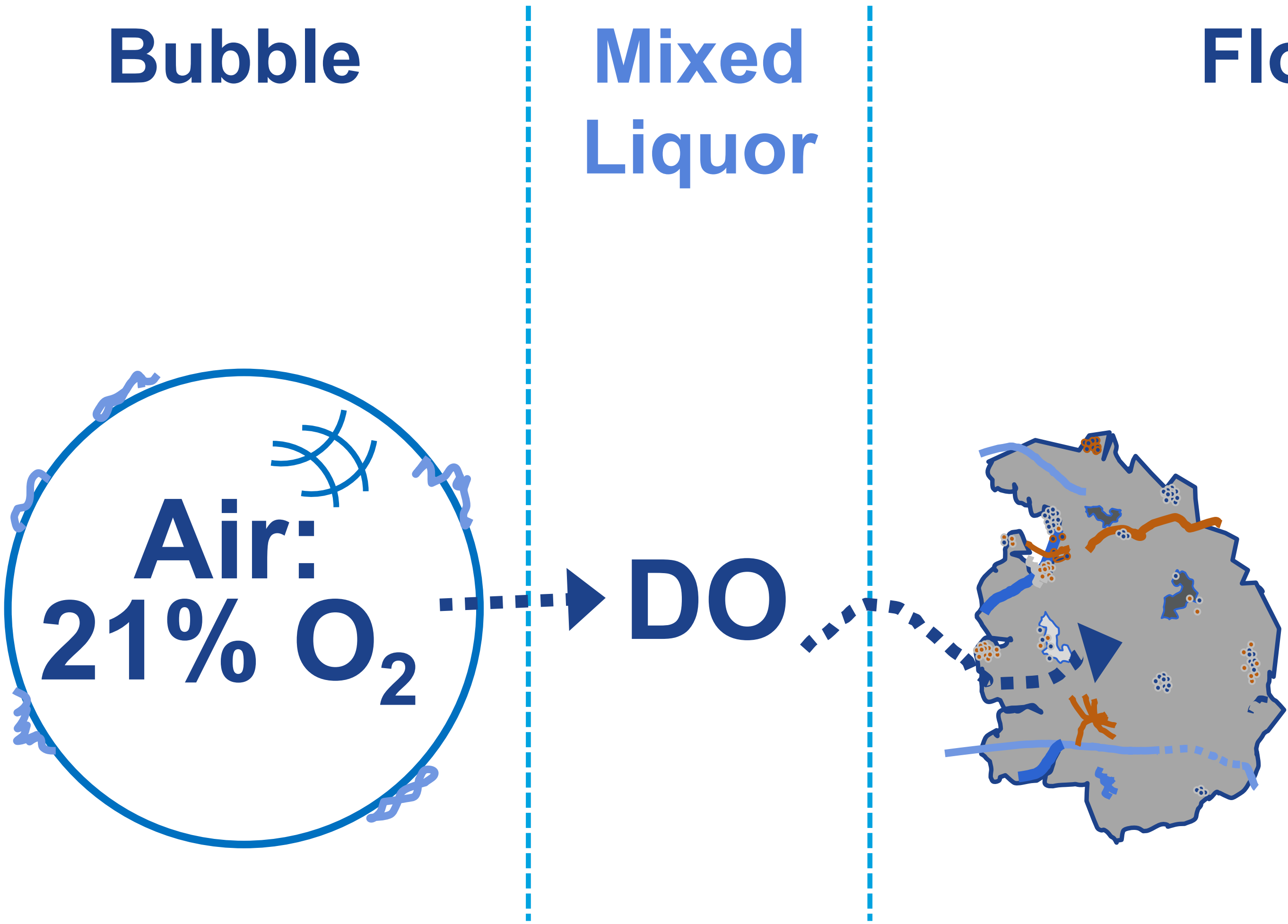
Another Problem With Inadequate DO: Small Floc Size



Insufficient DO to Drive Diffusion Results in Low/No DO in Center of Floc



Small Floc Settle Slowly, if at All

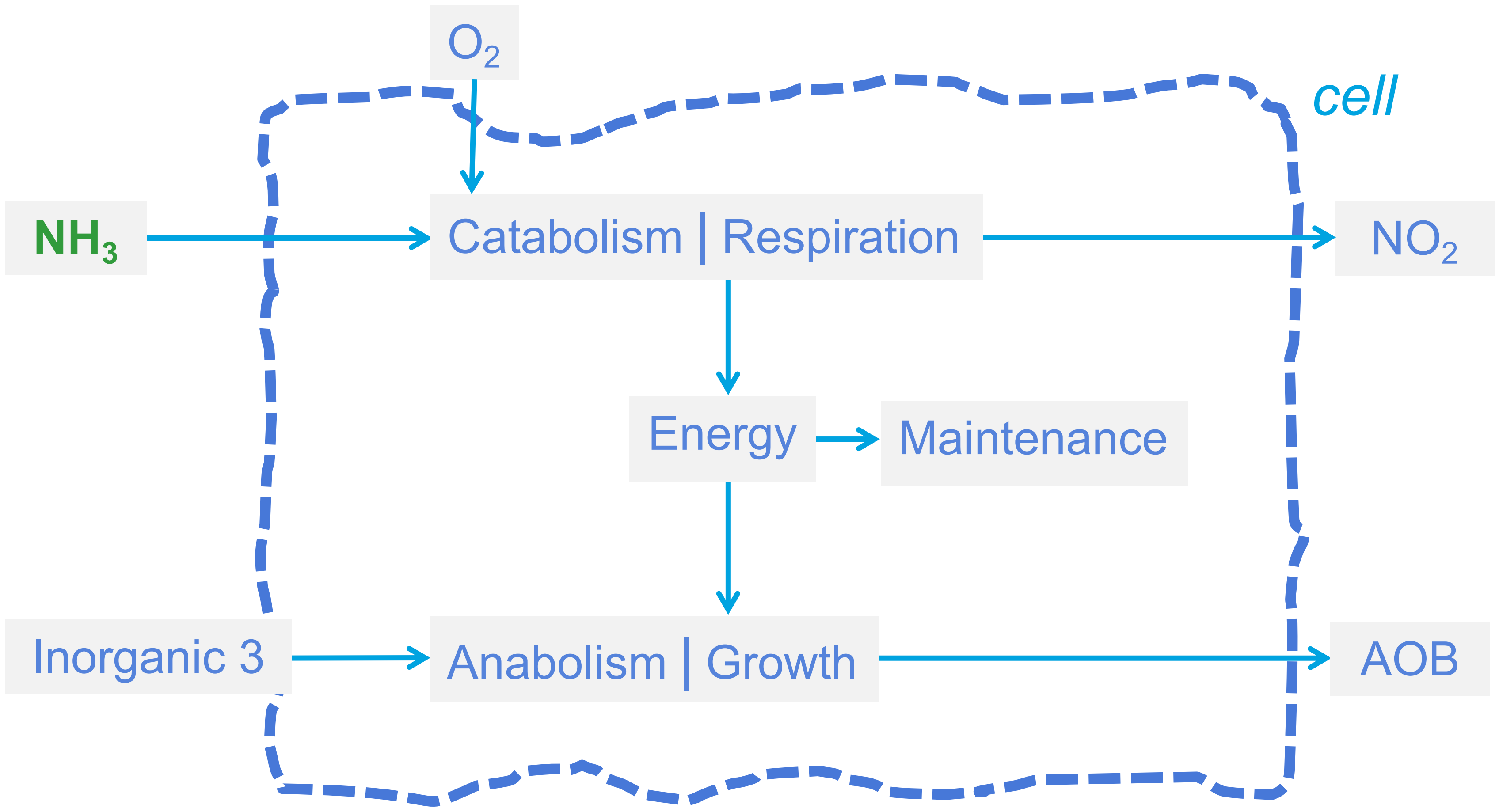


Nitrifiers are Autotrophs

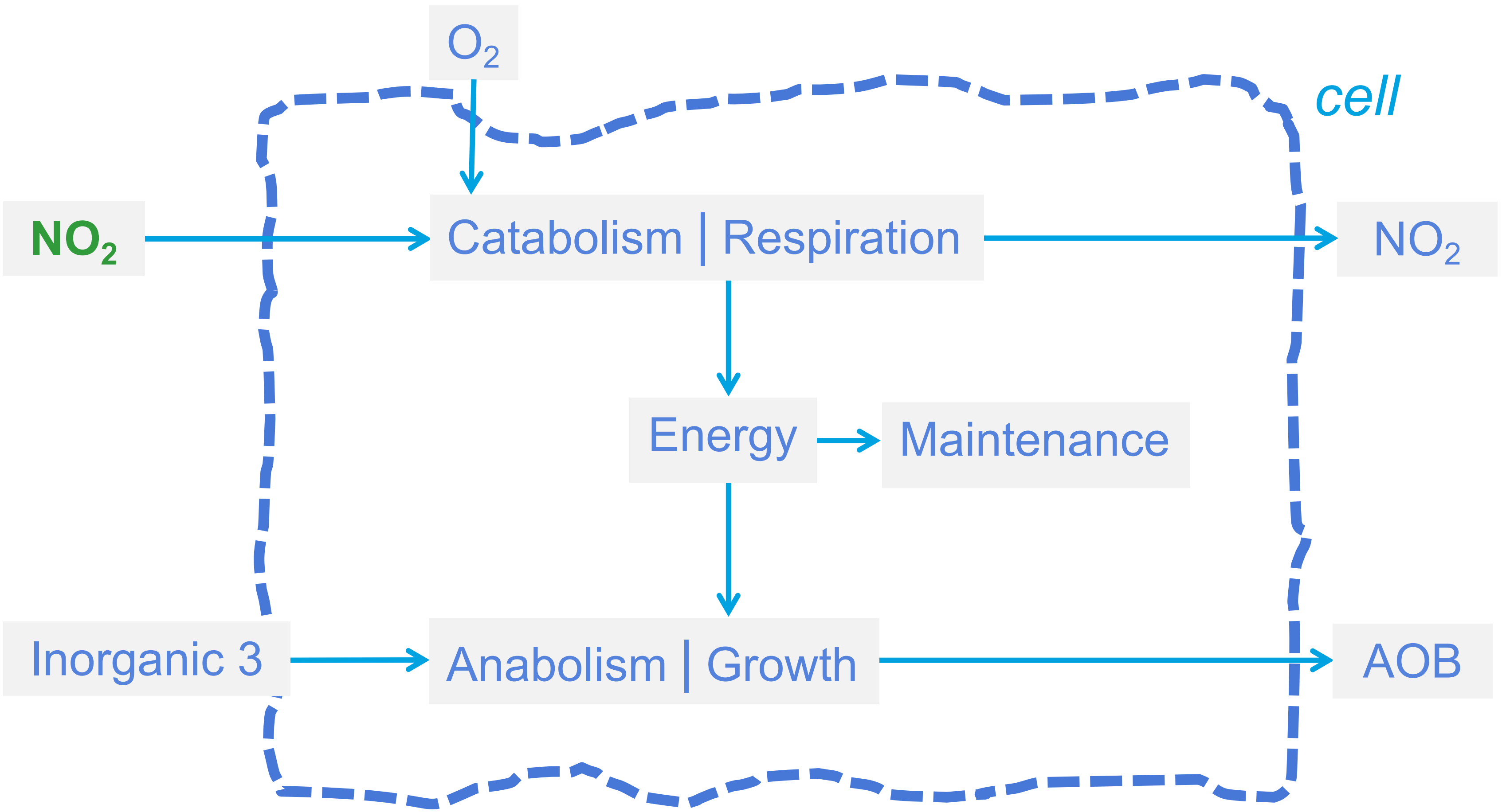
$$NH_4^+ \leftrightarrows H^+ + NH_3 \rightarrow NO_2^- \rightarrow NO_3^-$$

Ammonium Ammonia Nitrite Nitrate

Ammonia Oxidizing Bacteria (AOB)



Nitrite Oxidizing Bacteria (NOB)



Total Oxygen Needed to Oxidize NH_4^+ to NO_2^- and NO_3^- Determined from Stoichiometry

For AOB

$$NH_4^+ + 1\frac{1}{2}O_2 \rightarrow NO_2^- + H_2O + 2H^+$$

[Every 1 lb NH_4-N requires 3.4 lb O_2]

For AOB + NOB

$$NH_4^+ + 2O_2 \rightarrow NO_3^- + H_2O + 2H^+$$

[Every 1 lb NH_4-N requires 4.6 lb O_2]

Nitrification Proceeds as a "First-order Reaction" Two Hugely Important Consequences

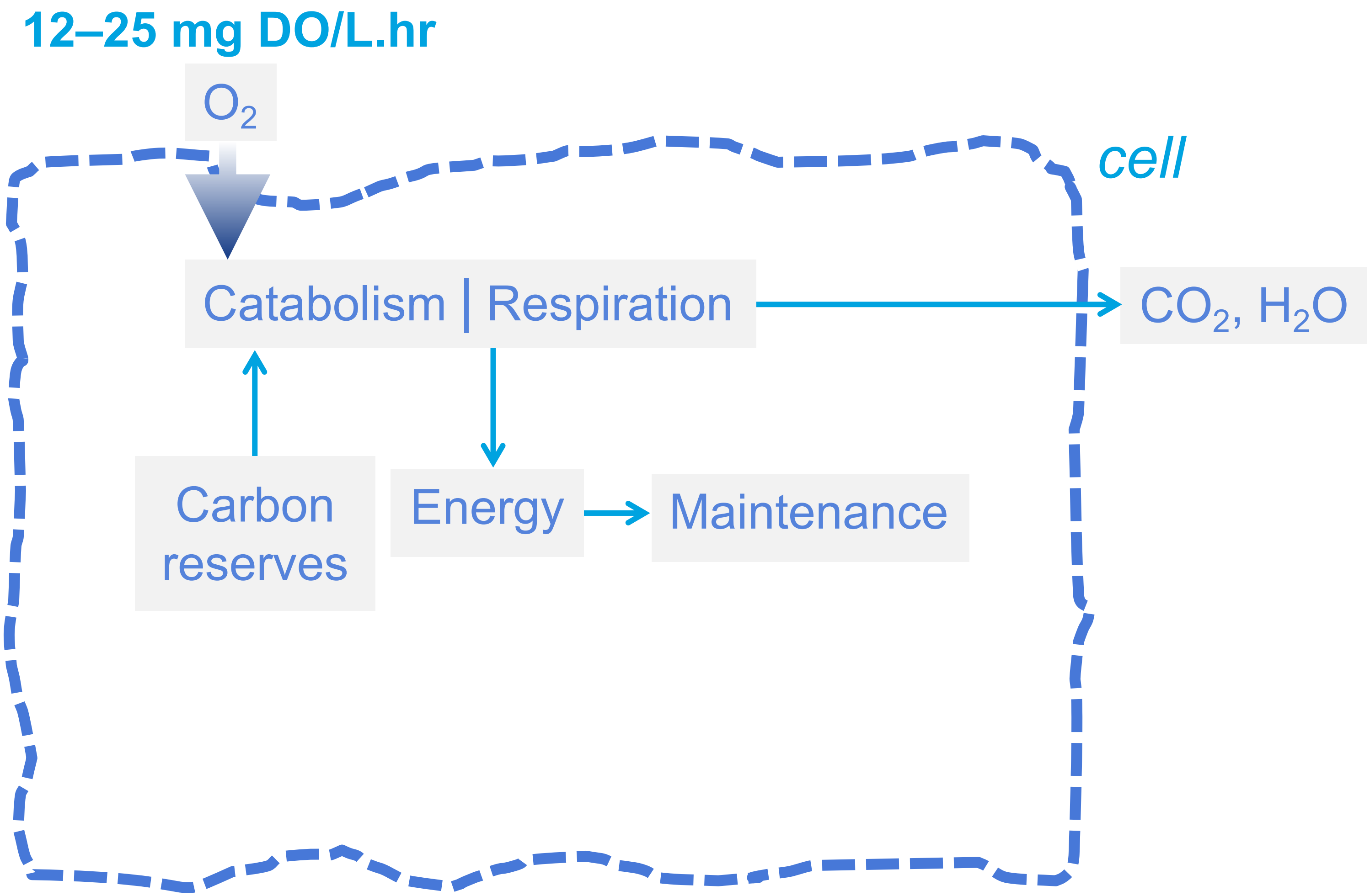
$$NH_4^+ + 2O_2 \rightarrow NO_3^- + H_2O + 2H^+$$

1. **Oxygen uptake rate (OUR)**
   during nitrification is constant
2. **As a result of No. 1**
   High ammonia concentrations
   do not require high DO concentrations

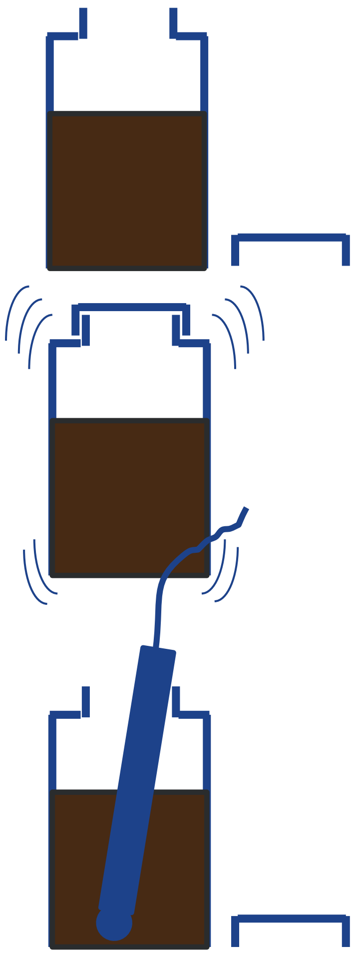
Nitrifiers are Strict Aerobes but Can't Compete When BOD Concentration is High

1. **Some inhibition**
   when DO is less than 1.5 mg/L
2. **Significant inhibition**
   when DO is less than 1.0 mg/L
3. **Complete inhibition**
   when DO is less than 0.5 mg/L
4. **Heterotrophs out-compete nitrifiers**
   for oxygen when the BOD concentration is high

Endogenous OUR (when BOD and NH_3 are gone) is Relatively Constant and Measurable



Simplified OUR Test Provides Tremendous Insight and Control



Collect mixed liquor sample
(~300 mL in 500-mL Nalgene)

Cap and shake to aerate

Insert DO probe

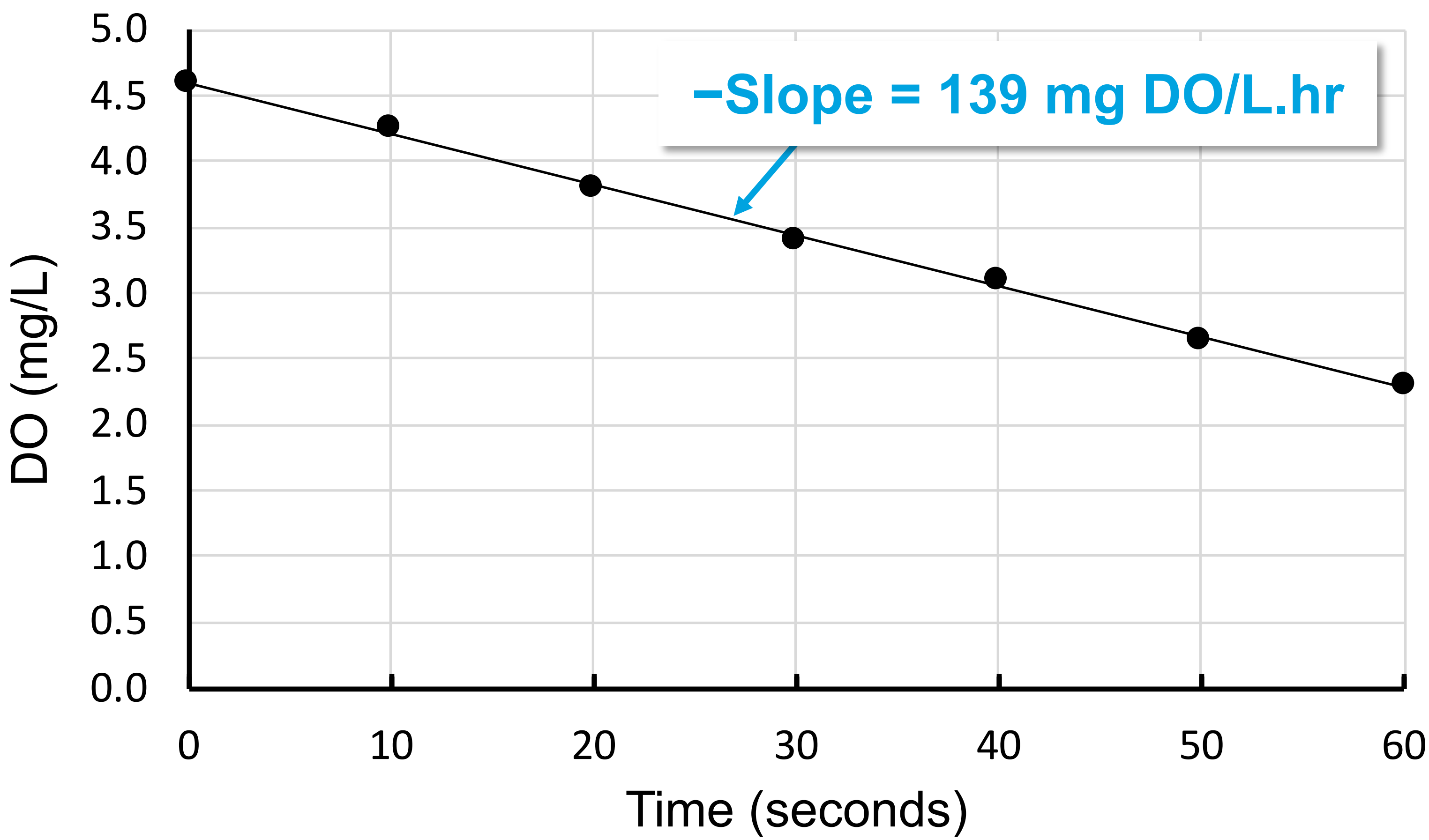
Once DO is falling constantly,
read DO as you start a stopwatch

Read DO every 10 sec for 60 sec

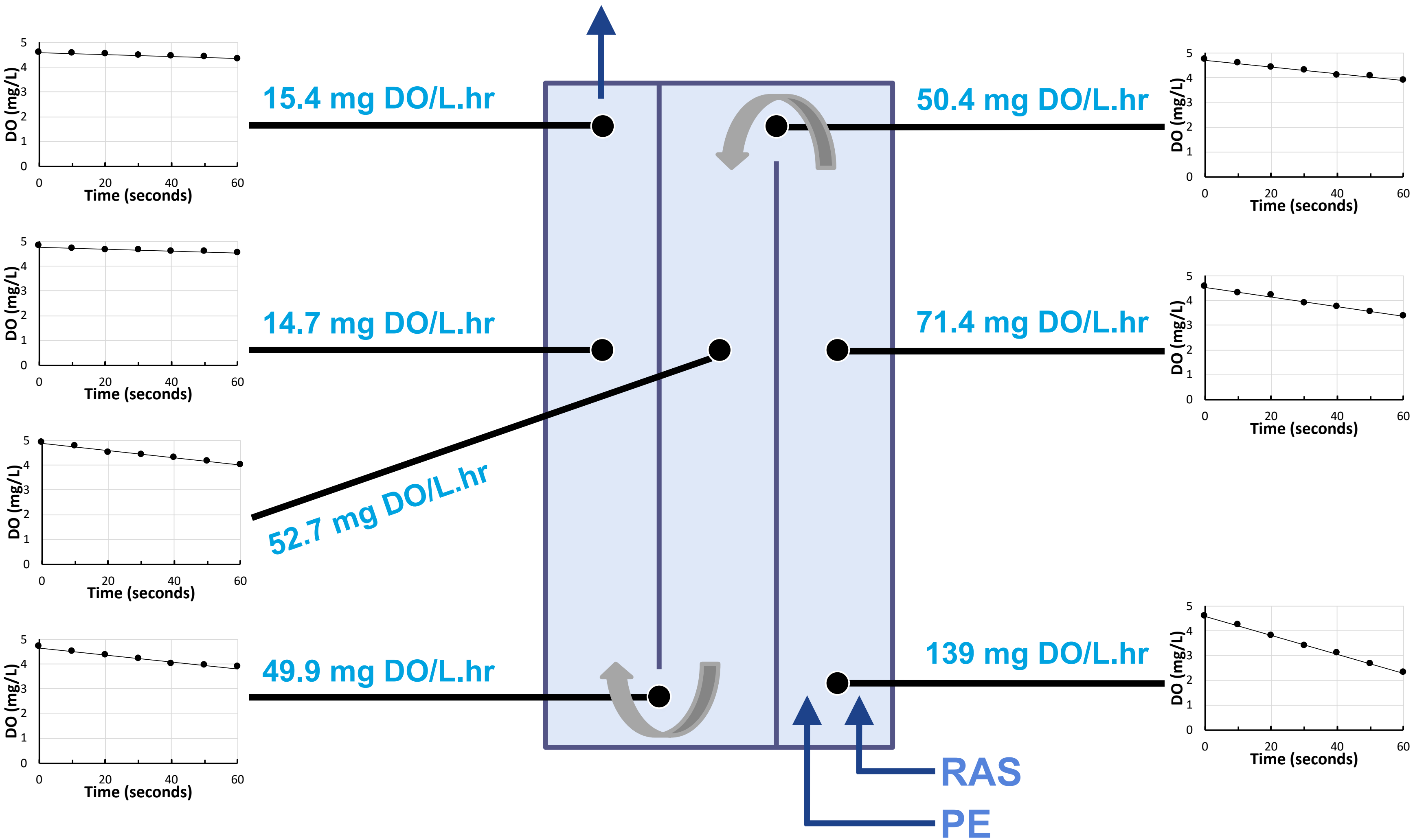
Plot DO (y-axis) as a function of seconds (x-axis)
to make sure decrease is linear

Calculate OUR, mg DO/L.hr, from slope

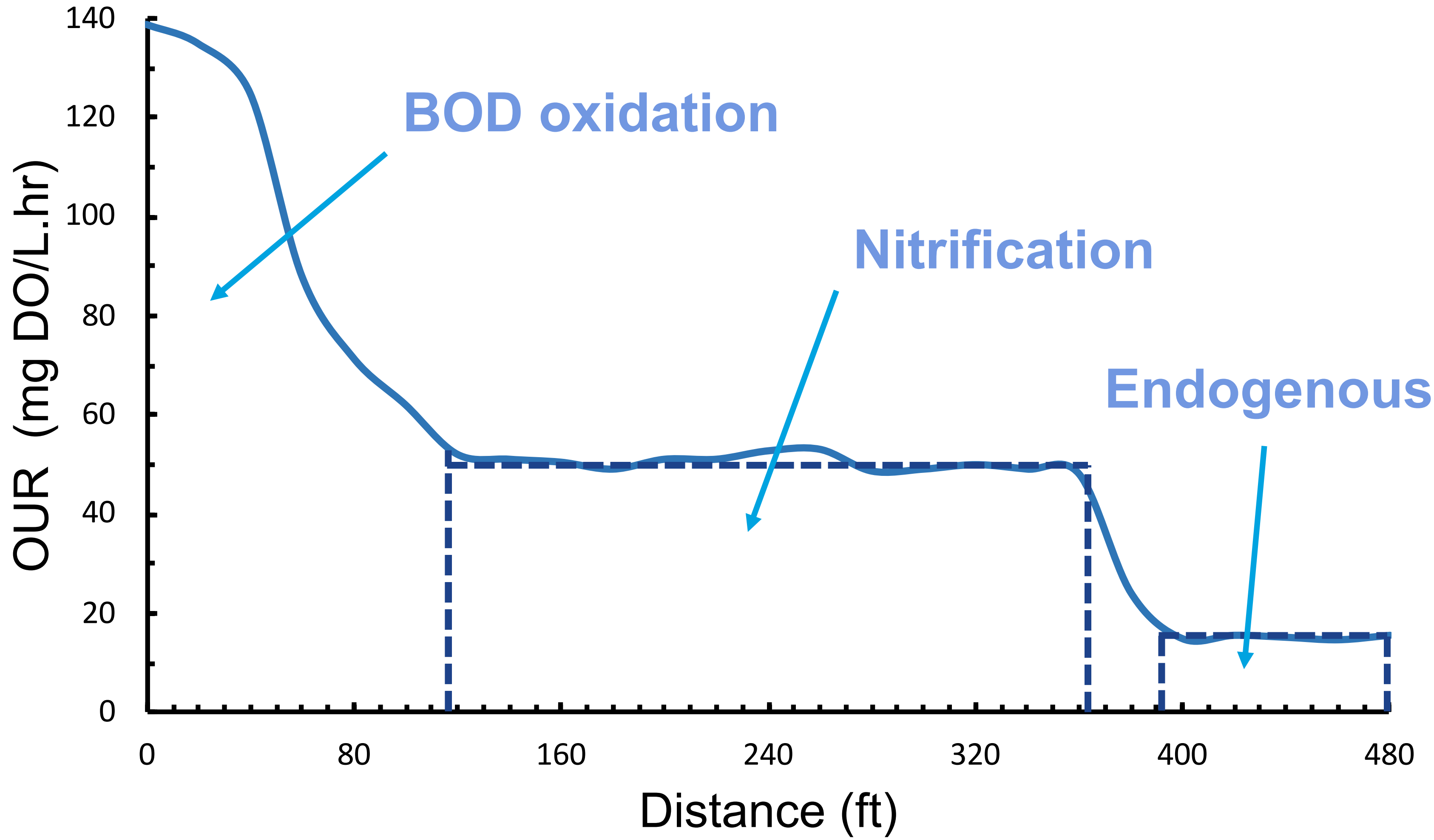
Results at the Beginning of an Aeration Basin



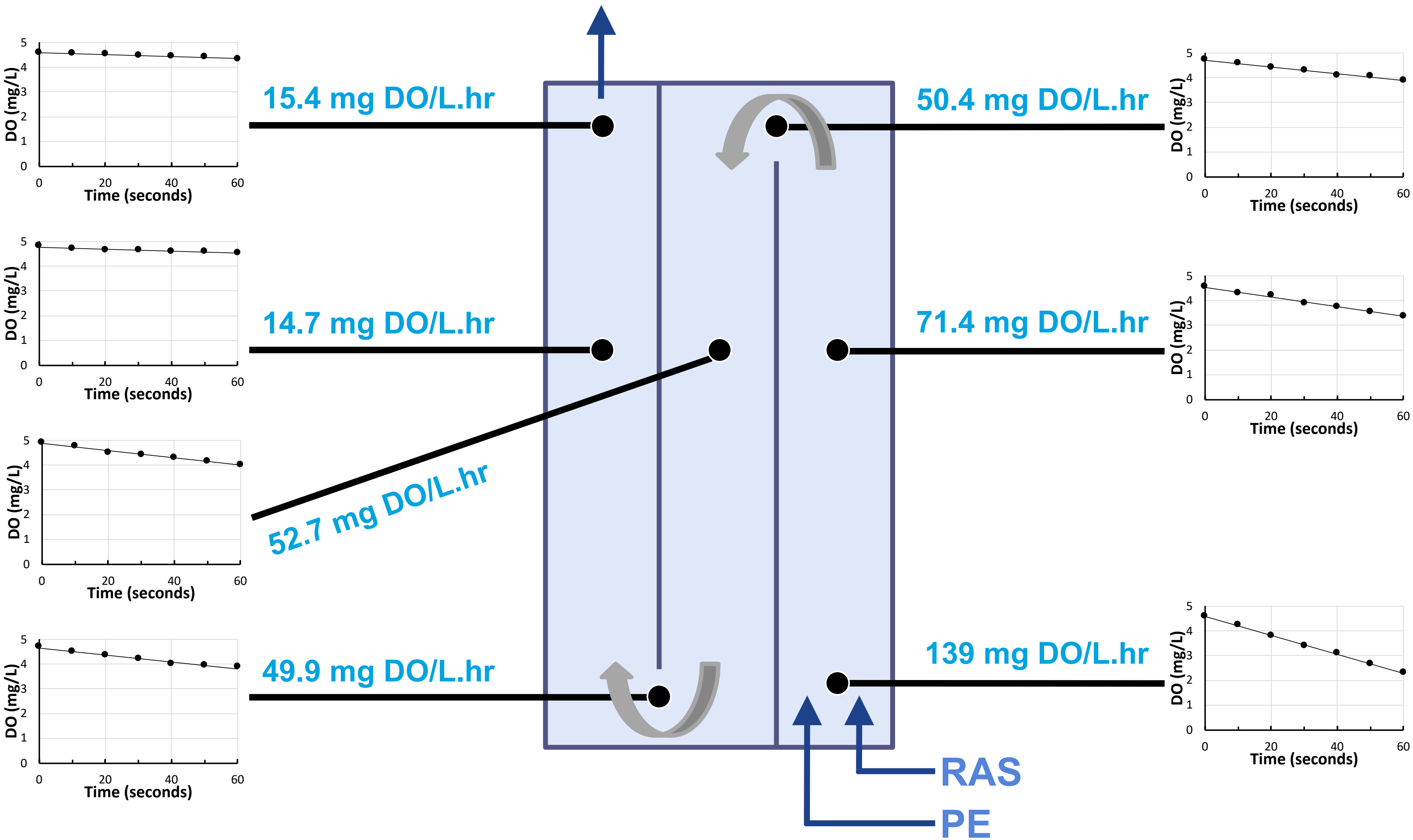
OUR Profile


15.4 mg DO/L.hr
14.7 mg DO/L.hr
52.7 mg DO/L.hr
49.9 mg DO/L.hr
50.4 mg DO/L.hr
71.4 mg DO/L.hr
139 mg DO/L.hr
RAS
PE
DO (mg/L)
Time (seconds)

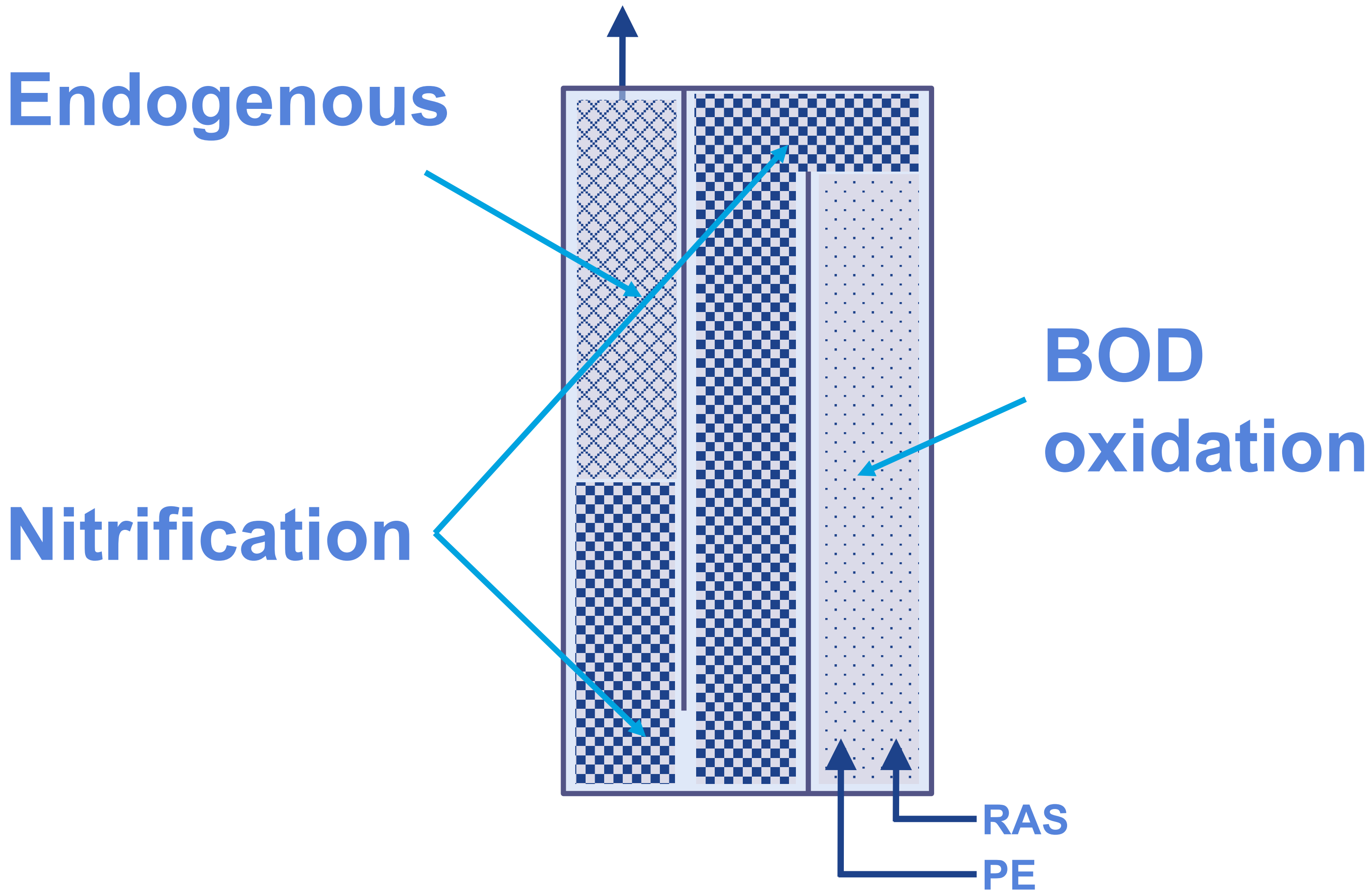
Subzones Delineated by OUR Profile



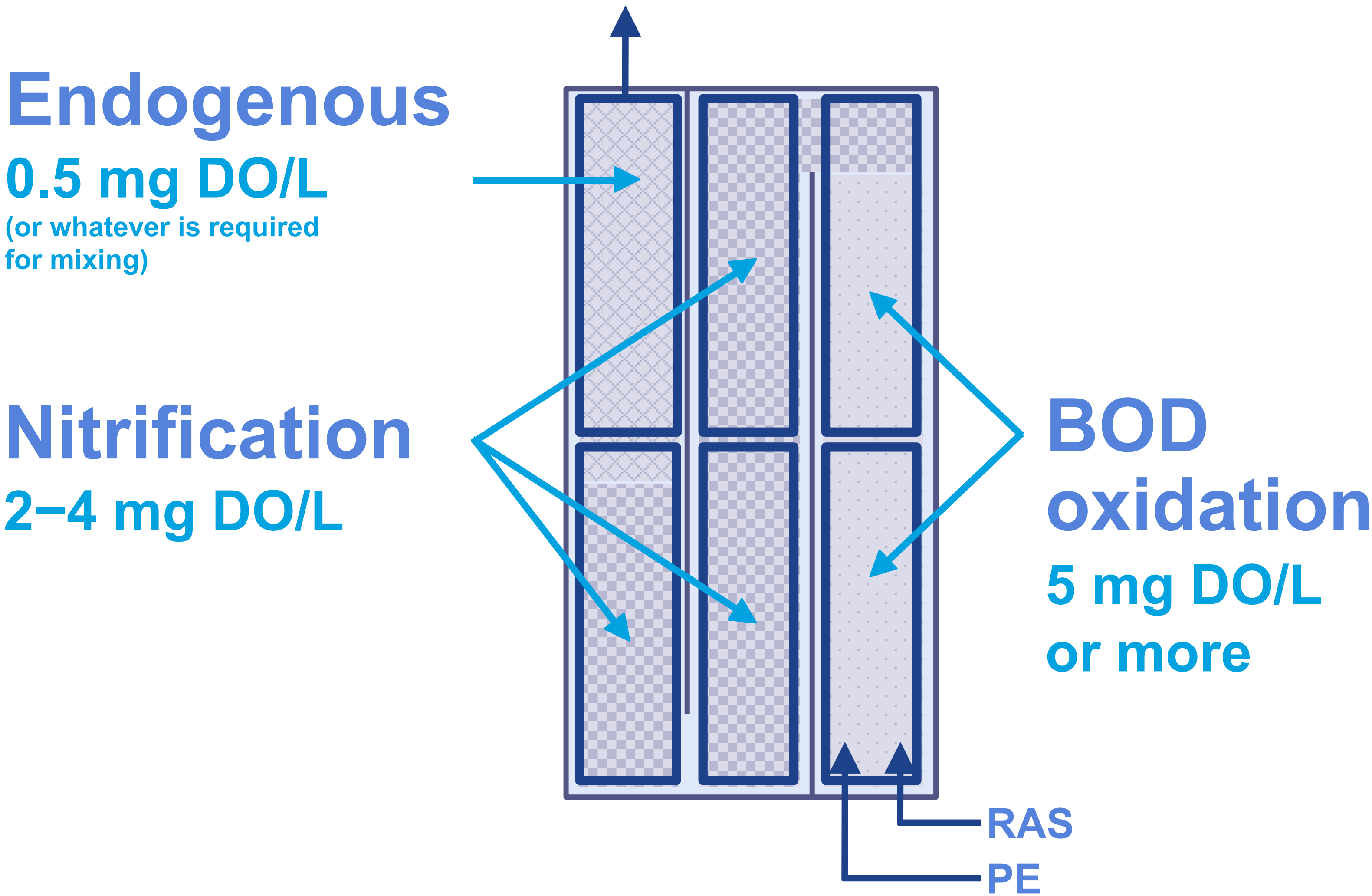
Subzones Identified



Subzones Identified



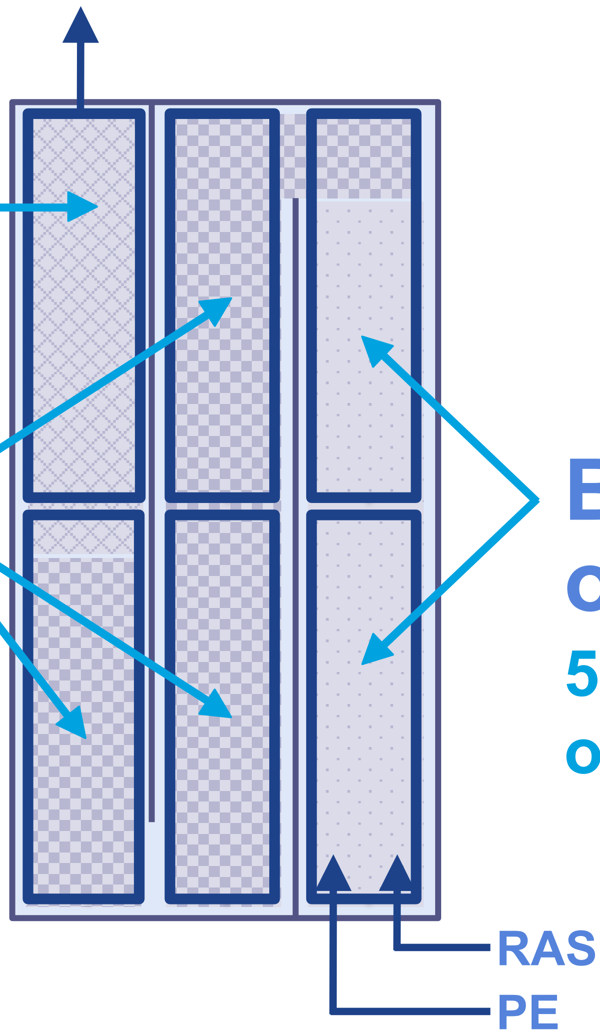
Different Subzones Have Different DO Set-Point Requirements



Recommendation of 2.0 mg DO/L Throughout
Not Enough Sometimes, Too Much Others

Endogenous
0.5 mg DO/L
(or whatever is required for mixing)

Nitrification
2–4 mg DO/L

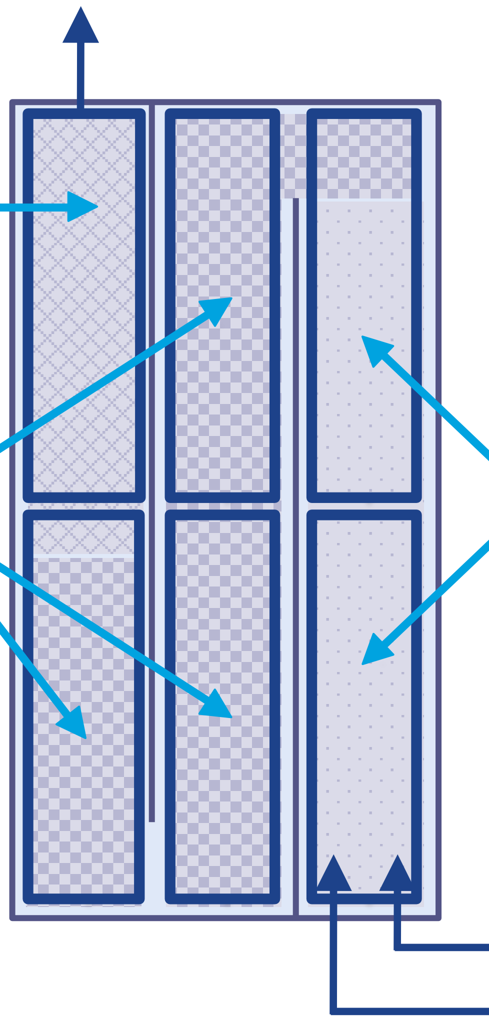


BOD oxidation
5 mg DO/L or more

Depending on Size of Endogenous Subzone, Huge Potential for Energy Savings

Endogenous
0.5 mg DO/L
(or whatever is required for mixing)

Nitrification
2–4 mg DO/L



BOD oxidation
5 mg DO/L or more

Takeaway Process Knowledge Takes Guesswork Out of Setting DO Targets

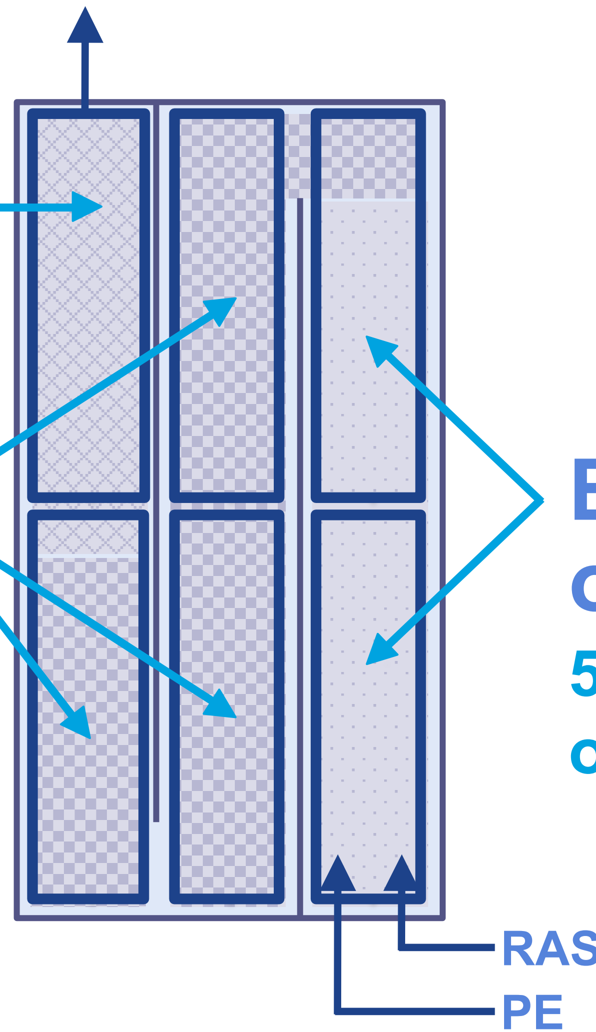
Endogenous

0.5 mg DO/L

(or whatever is required for mixing)

Nitrification

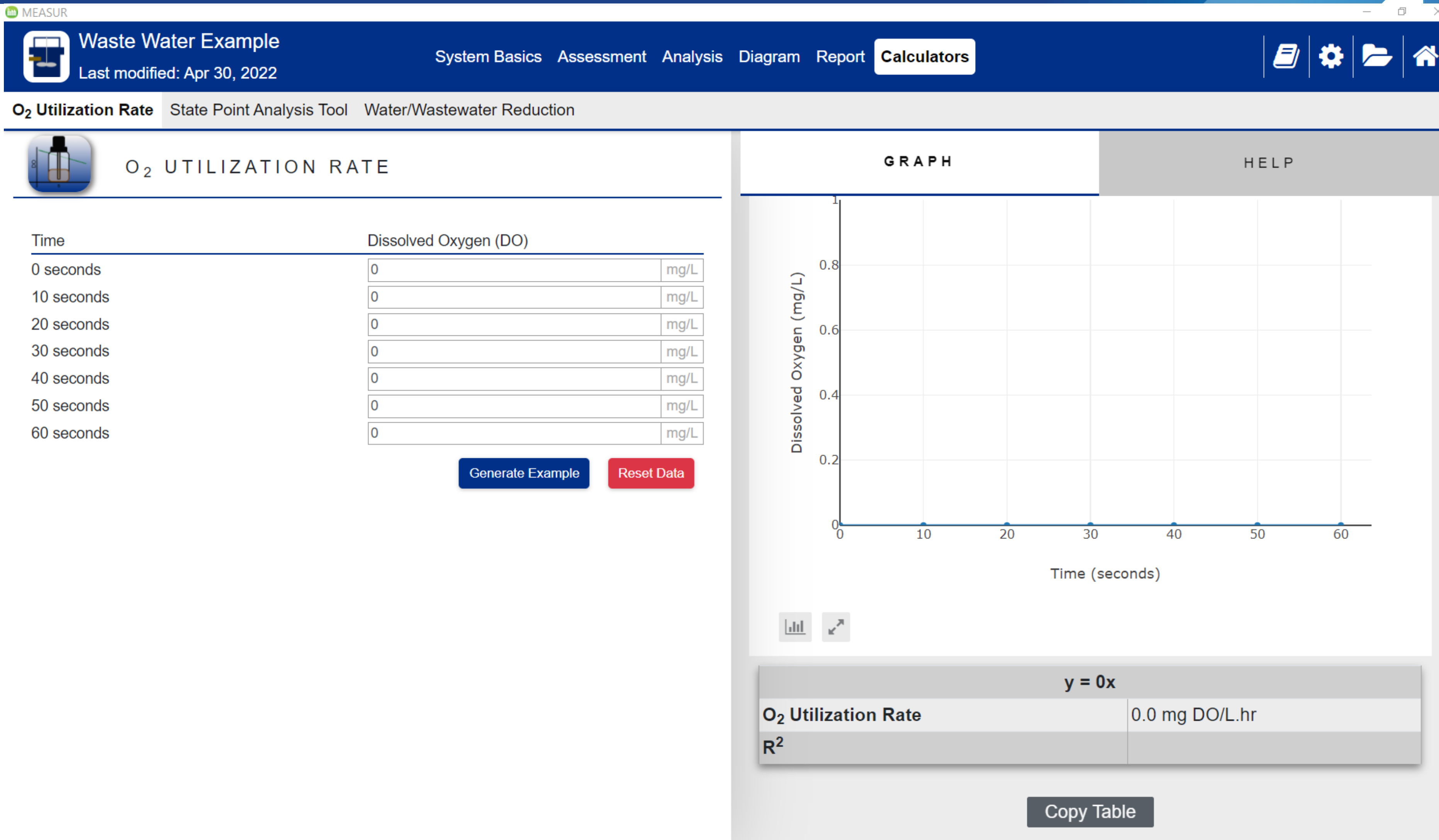
2–4 mg DO/L



BOD oxidation

5 mg DO/L or more

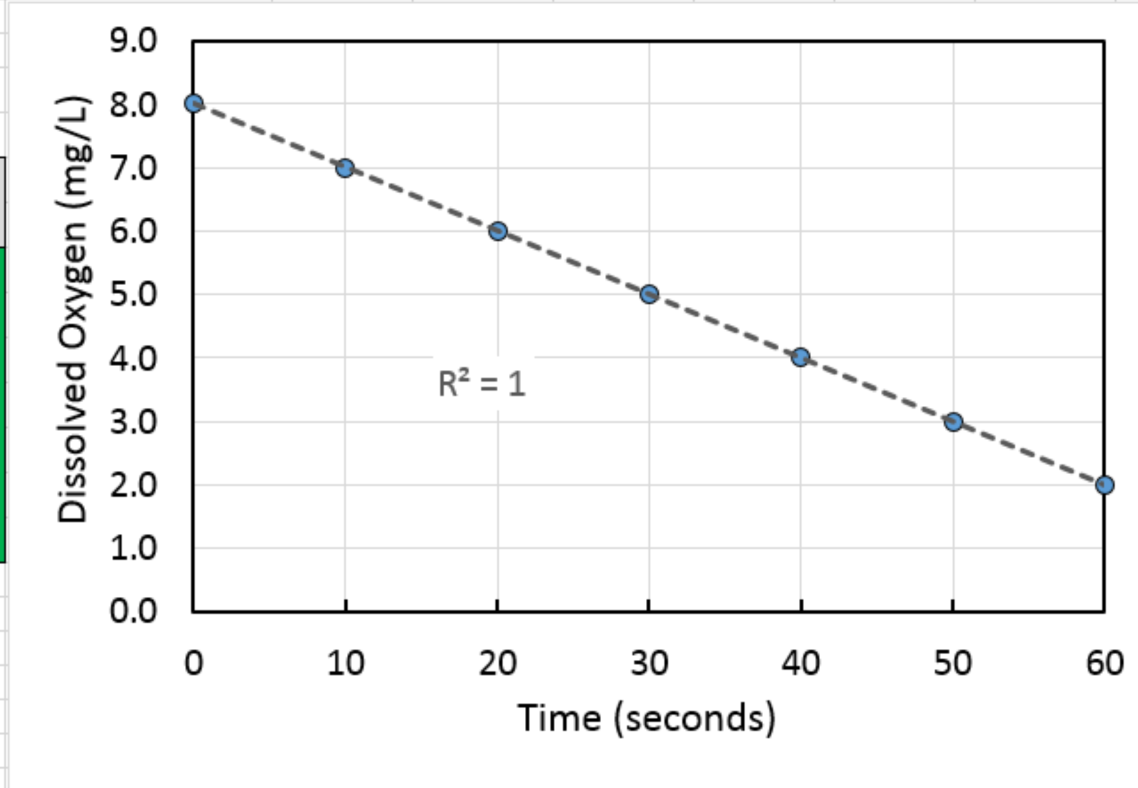
OUR Example & MEASUR



OUR Exercise

Enter DO data in green area

Time (seconds)	DO (mg/L)
0	8.00
10	7.00
20	6.00
30	5.00
40	4.00
50	3.00
60	2.00



OUR = 360.0 mg DO/L.hr

Break

Aeration/Secondary Treatment

Coarse Bubble Aeration

Aeration → *Priorities!*

1. **Satisfy the process need** (BOD conversion).
2. **Minimize the residual.**
3. ~~**Keep solids in suspension.**~~

Avoid *if you can!*

This is what mixers are for!

Header Pressure

Distance from diffuser to water surface in feet divided by 2.31 = minimum header pressure in PSIG to form a bubble.

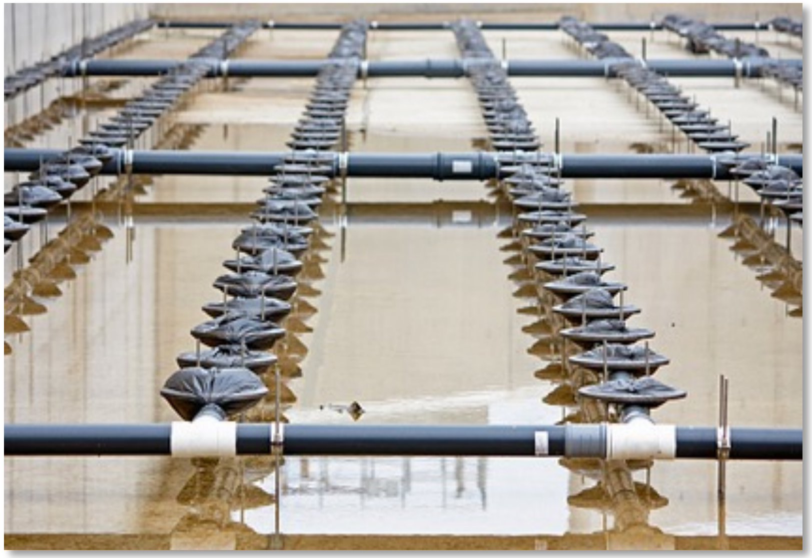
Exercise - Aeration Pressure

3 IMPACT OF BLOWER PRESSURE ON ENERGY

Disch. pressure	Reduction in pressure of ___ psig				
	-0.2	-0.4	-0.6	-0.8	-1.0
12	1.3%	2.7%	4.0%	5.4%	6.7%
11	1.5%	2.9%	4.4%	5.9%	7.4%
10	1.6%	3.3%	4.9%	6.6%	8.3%
9	1.8%	3.7%	5.5%	7.4%	9.3%
8	2.1%	4.2%	6.3%	8.4%	10.6%
7	2.4%	4.8%	7.3%	9.7%	12.2%

*Assumes 70% blower eff & 92% motor/drive eff

Aeration



Fine bubble diffused aeration High efficiency, moderate maintenance

Mechanical aeration Low efficiency, high maintenance

Jet aeration High efficiency, low-to-moderate maintenance

Coarse bubble diffused aeration Low efficiency, low maintenance

DO Residual Aeration Impact

2 IMPACT OF DO LEVELS ON ENERGY

Saturated DO

DO in basin = driving force for oxygen transfer
Driving force UP means Energy goes DOWN

DO rule of thumb

0.5 mg/l reduction creates ~ 6% energy savings

DO calibration & cleaning

A probe that reads 10% low (e.g. 2.0 when actual is 2.2) is costing you 2.4% at the blower.

DO level increases

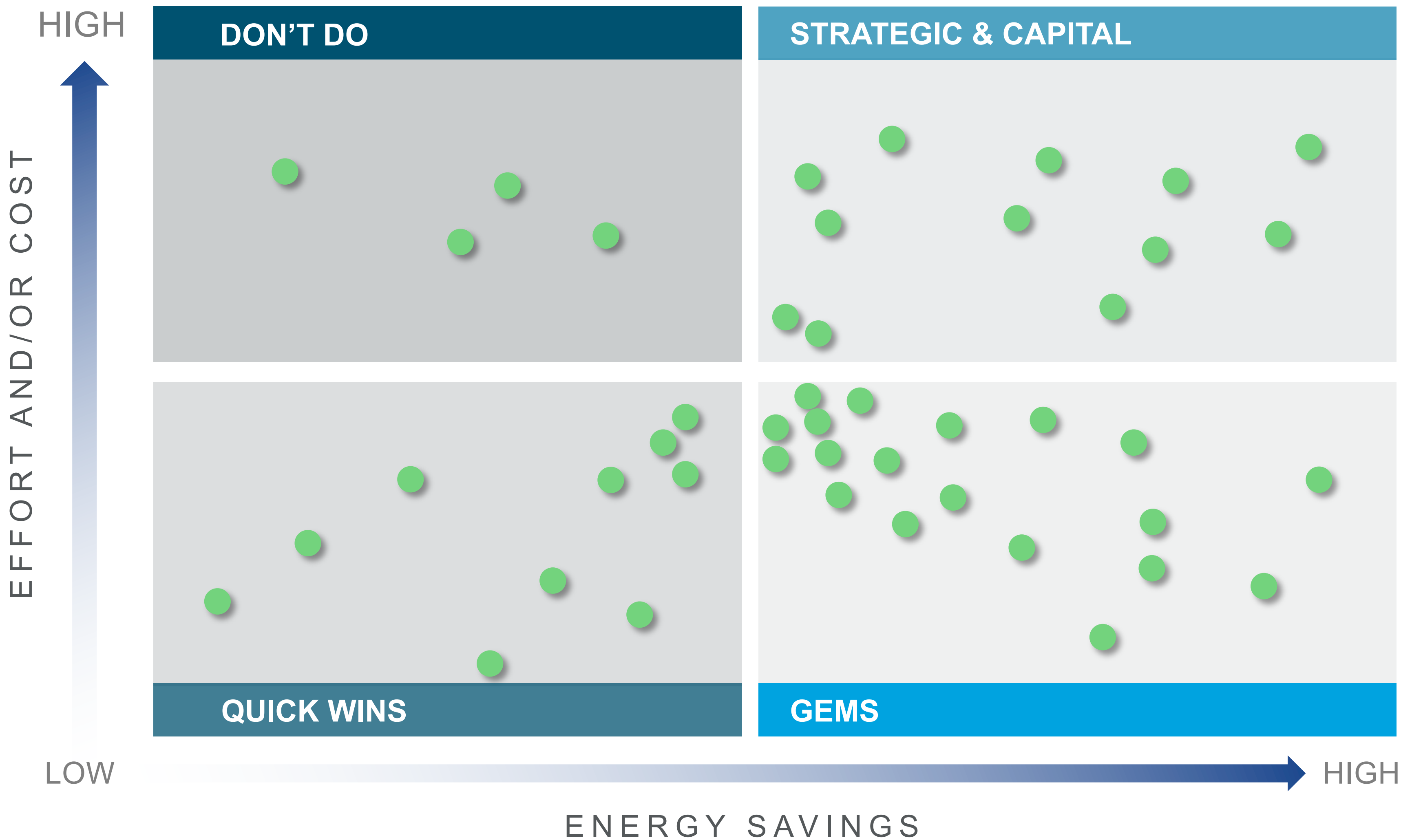
As mixed liquor temp increases, the impact of elevated DO levels increases.

IMPACT OF AVERAGE DO LEVEL ON BLOWER ENERGY

Mixed liquor temp		DO sat	Energy savings potential if DO reduced from __ to 2.0 mg/l			
°C	°F	mg/l	2.5	3	4	5
0	32	14.6	4.0%	7.9%	15.9%	23.8%
2	36	13.8	4.2%	8.5%	16.9%	25.4%
5	41	12.8	4.6%	9.3%	18.5%	27.8%
10	50	11.3	5.4%	10.8%	21.5%	32.3%
15	59	10.1	6.2%	12.3%	24.7%	37.0%
20	68	9.1	7.0%	14.1%	28.2%	42.3%
25	77	8.2	8.1%	16.1%	32.3%	48.4%

NOTE Higher impact as elevation increases

Value Matrix



FANS AND ODOR CONTROL

Fans and Odor Control

What You Can Control to Reduce Energy

Odor Control

HVAC

Temperature

Heat Recovery strategies

Control Monitoring Point

Seasonal auto settings
Occupied vs. unoccupied auto settings
Clean or replace air filters
Fan speed (VFD or sheave change)

Opportunity Register Thoughts?

Opportunity #	Opportunity Name	Description	Location	System*	Submitted By

Turning Ideas Into Savings

List your "top three" ideas

List the motor equipment involved in the table in your Workbook:

Equipment	HP	Current runtime	New runtime

Estimate savings

Participation Raffle

Tickets, please!

Closing

See You Next Tuesday!

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