Seawater

Earth is an Ocean Planet

Topics

- Origin of the Ocean and Atmosphere
- Hydrologic Cycle
- Biogeochemical Cycle
- Seawater Salinity
- Variations in Seawater Chemistry
- Carbonic Acid System

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- Variations in Seawater Chemistry
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Variations in Seawater Chemistry

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Most seawater constituents are nonconservative

Major Constituents are Conservative

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- Ocean is well mixed

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- Ocean is well mixed
- However, the concentrations of the other constituents can vary significantly

Major Constituents are Conservative

- Major constituent concentrations are conservative, so they are relatively uniform
- Ocean is well mixed
- However, the concentrations of the other constituents can vary significantly
- See large variations in the concentrations of most minor constituents, trace elements, and gases

Salinity Variations

Salinity Variations

- Two primary types of variations:

Salinity Variations

- Two primary types of variations:

1. Vertical variations

Salinity Variations

- Two primary types of variations:
  1. Vertical variations
  2. Horizontal variations

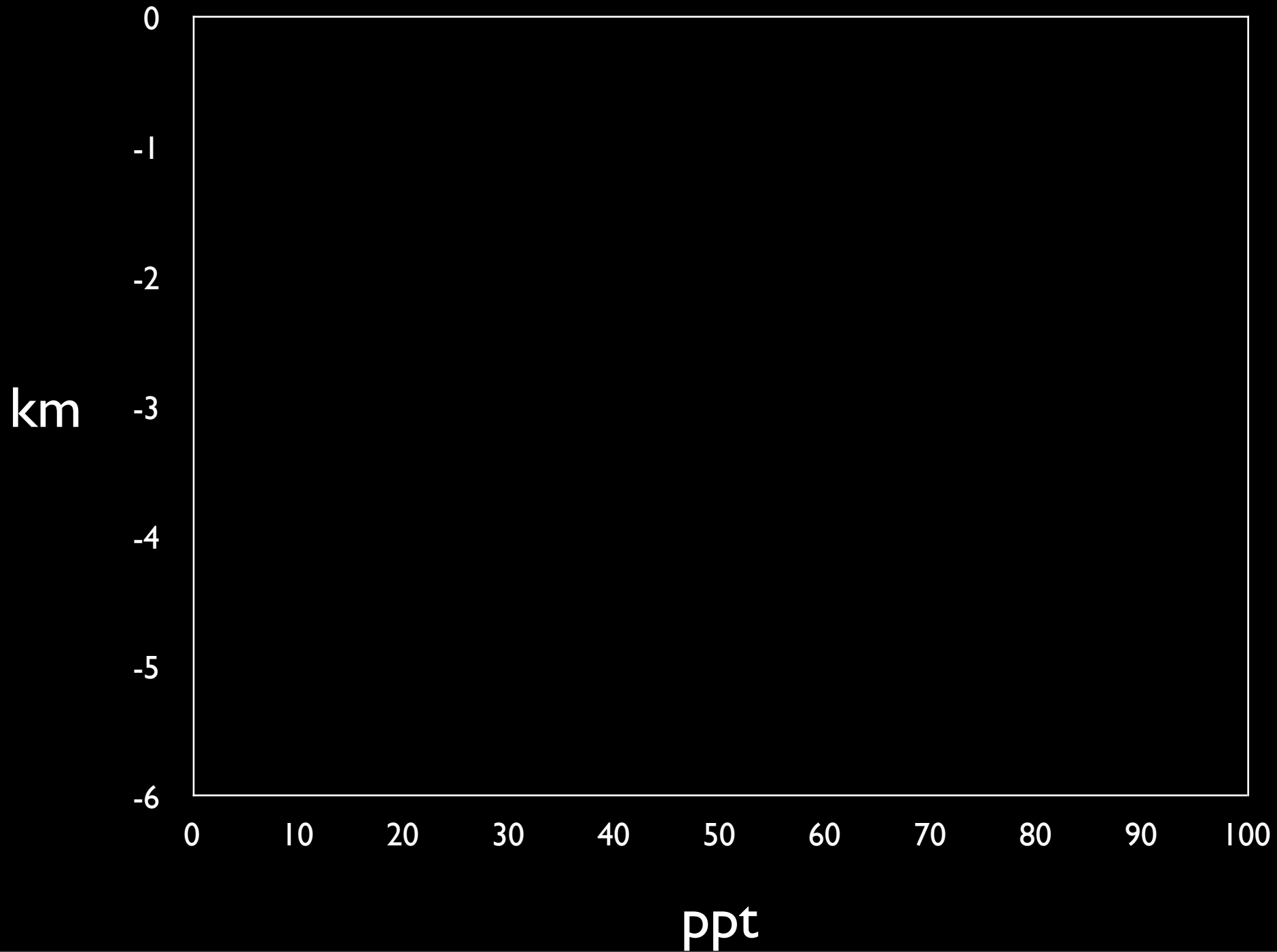
Vertical Variations

Vertical Variations

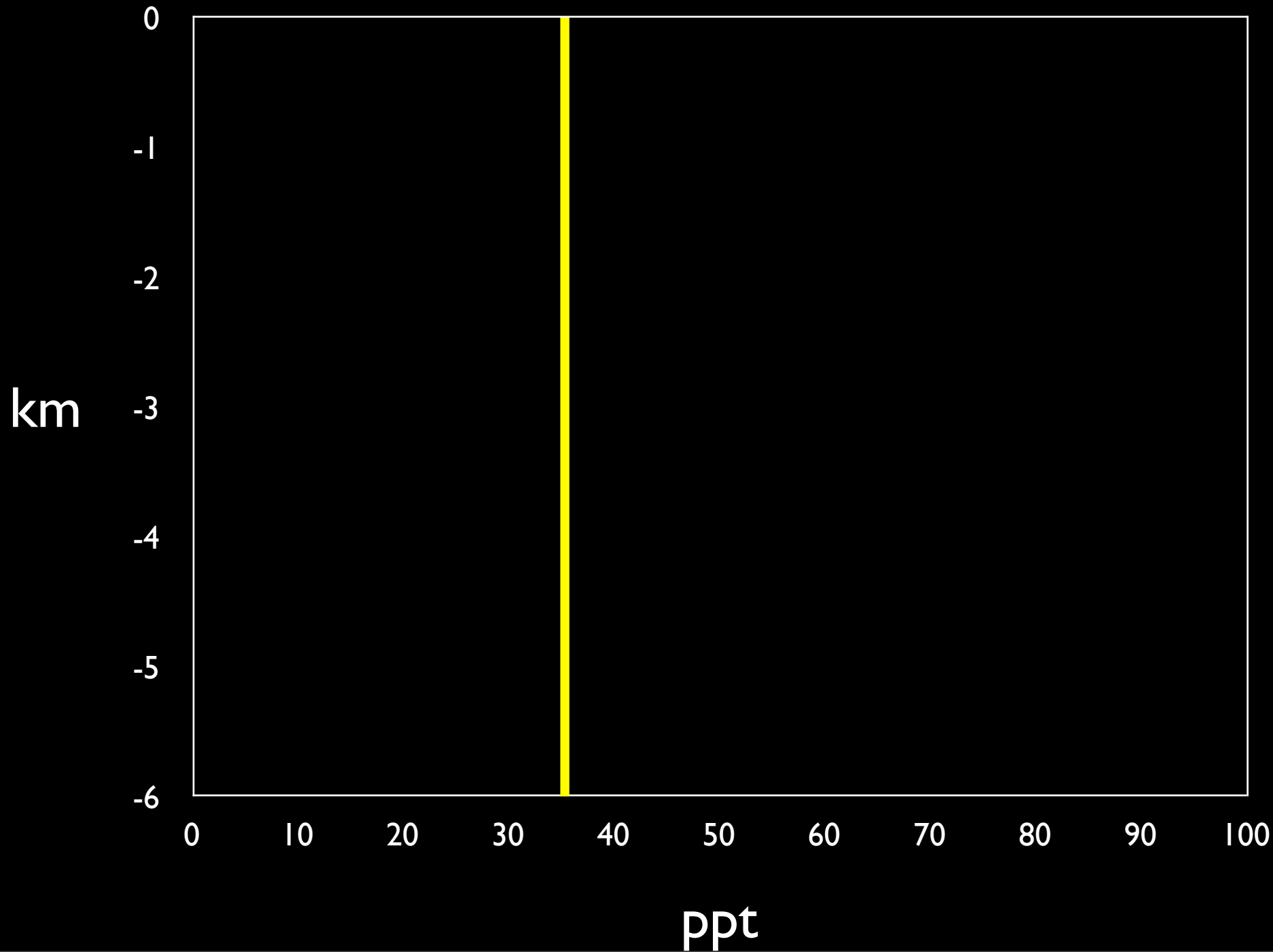
Question:

Describe a plot of the vertical variations for the major constituents

Major Constituents Vertical Variation Pattern



Major Constituents Vertical Variation Pattern



Vertical Variations:

Minor Constituents, Trace Elements, and Gases

Vertical Variations:
Minor Constituents, Trace Elements, and Gases

- Most dramatic change in the upper 1 km

Vertical Variations:
Minor Constituents, Trace Elements, and Gases

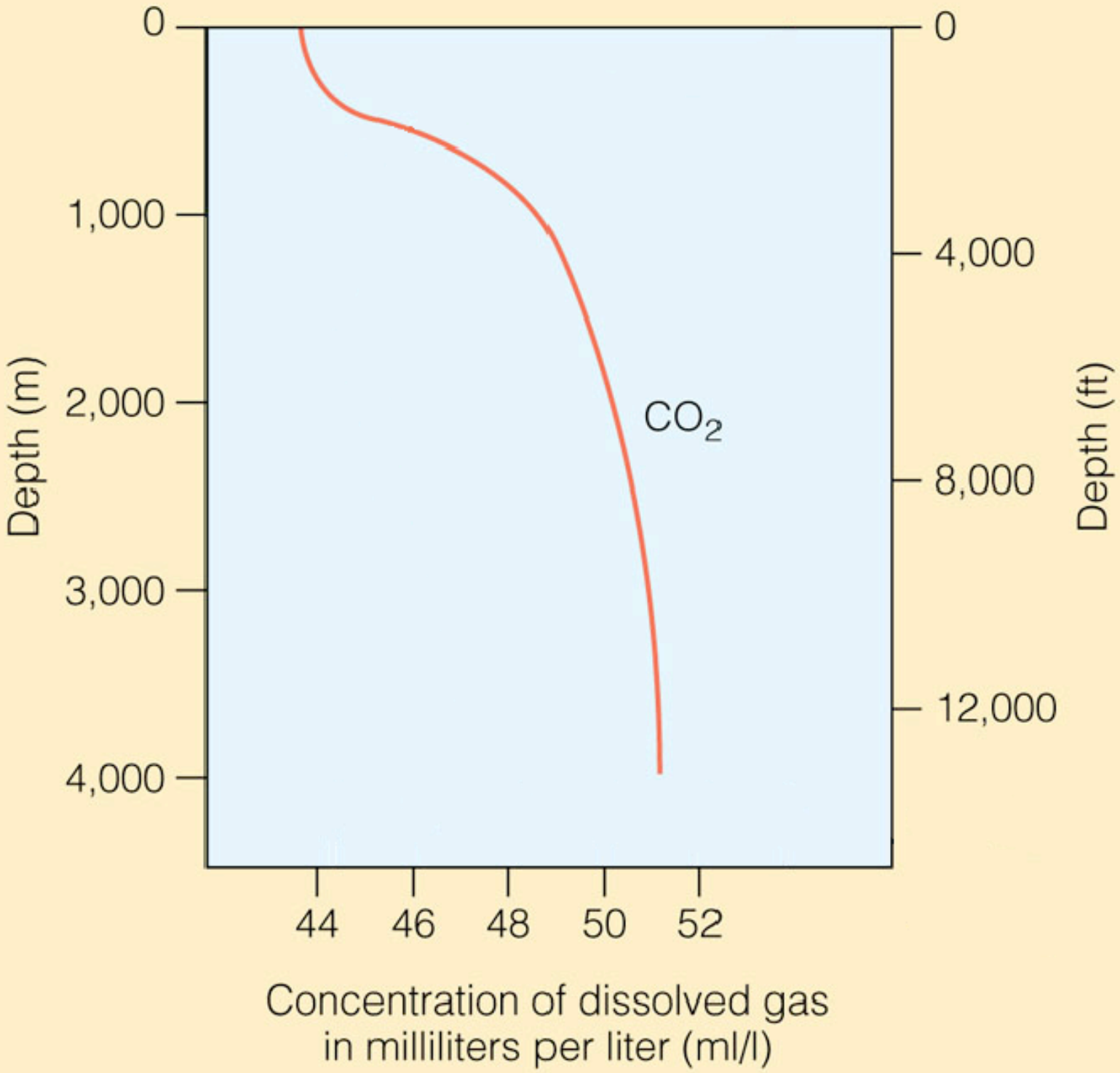
- Most dramatic change in the upper 1 km
- Primary vertical variation pattern:

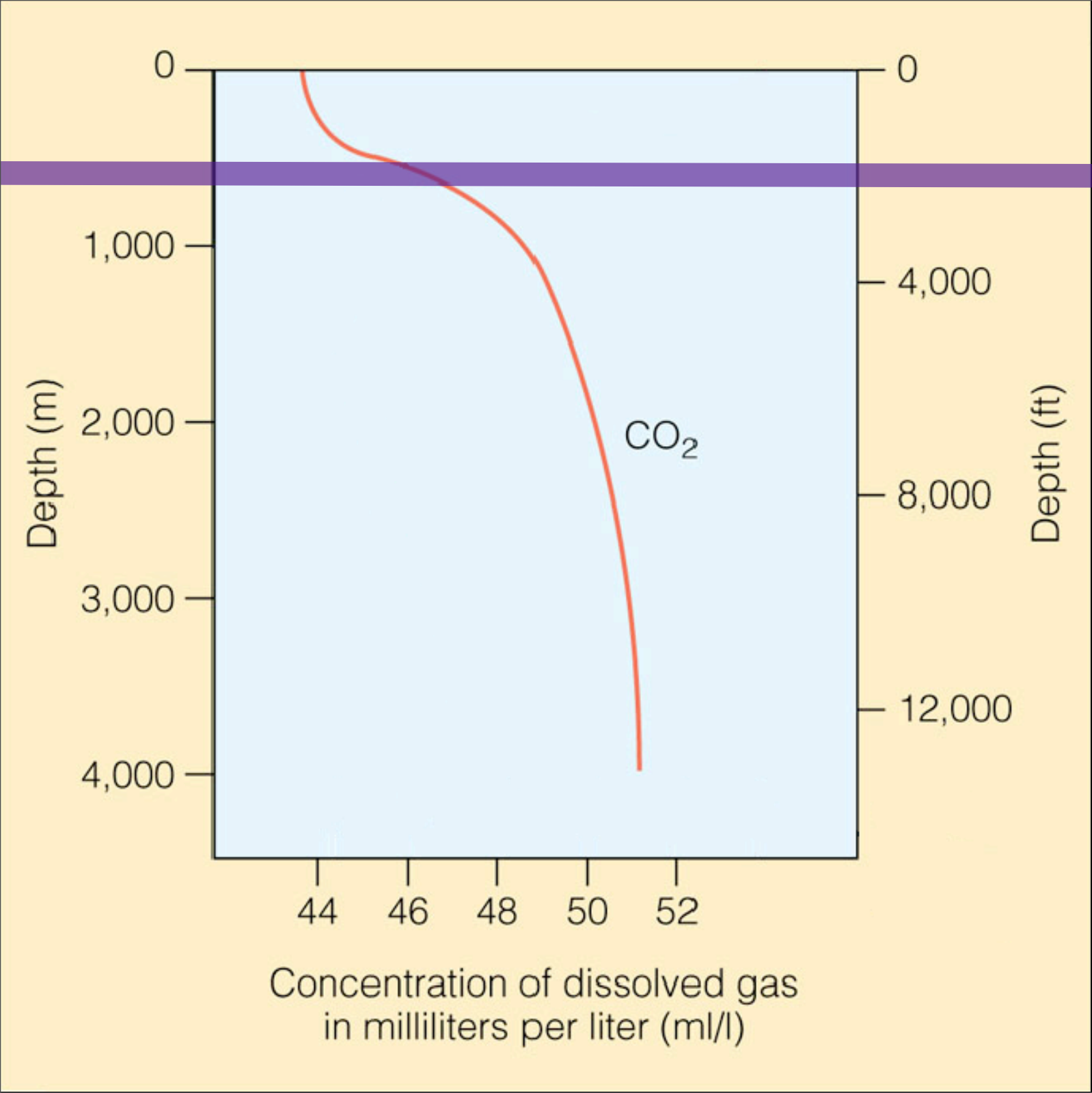
Vertical Variations:
Minor Constituents, Trace Elements, and Gases

- Most dramatic change in the upper 1 km
- Primary vertical variation pattern:
  - Depletion in the surface layer

Vertical Variations:
Minor Constituents, Trace Elements, and Gases

- Most dramatic change in the upper 1 km
- Primary vertical variation pattern:
  - Depletion in the surface layer
  - Enrichment at depth


0
1,000
2,000
3,000
4,000
Depth (m)
0
4,000
8,000
12,000
Depth (ft)
CO_2
44
46
48
50
52
Concentration of dissolved gas
in milliliters per liter (ml/l)


0
1,000
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Depth (m)
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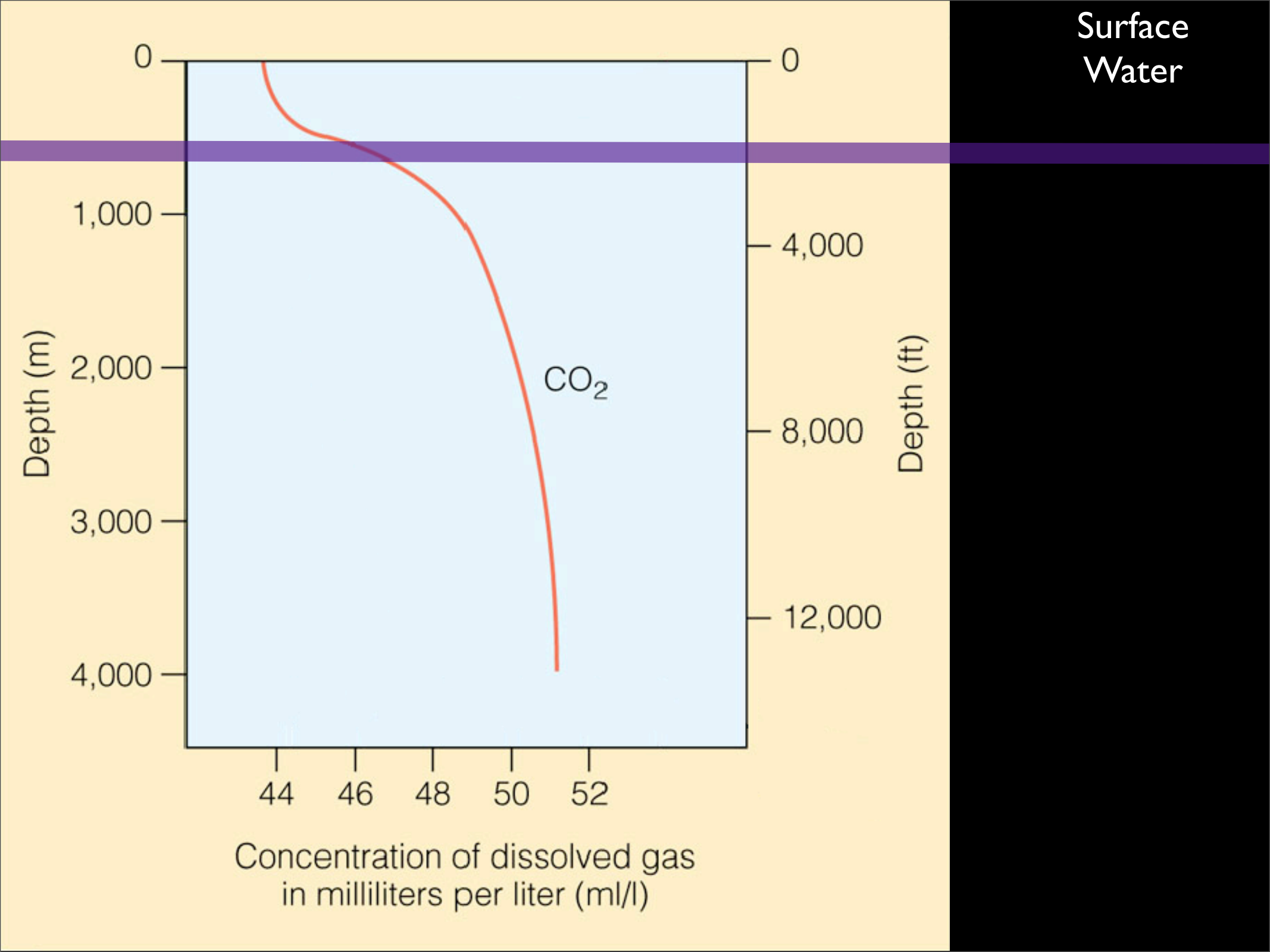
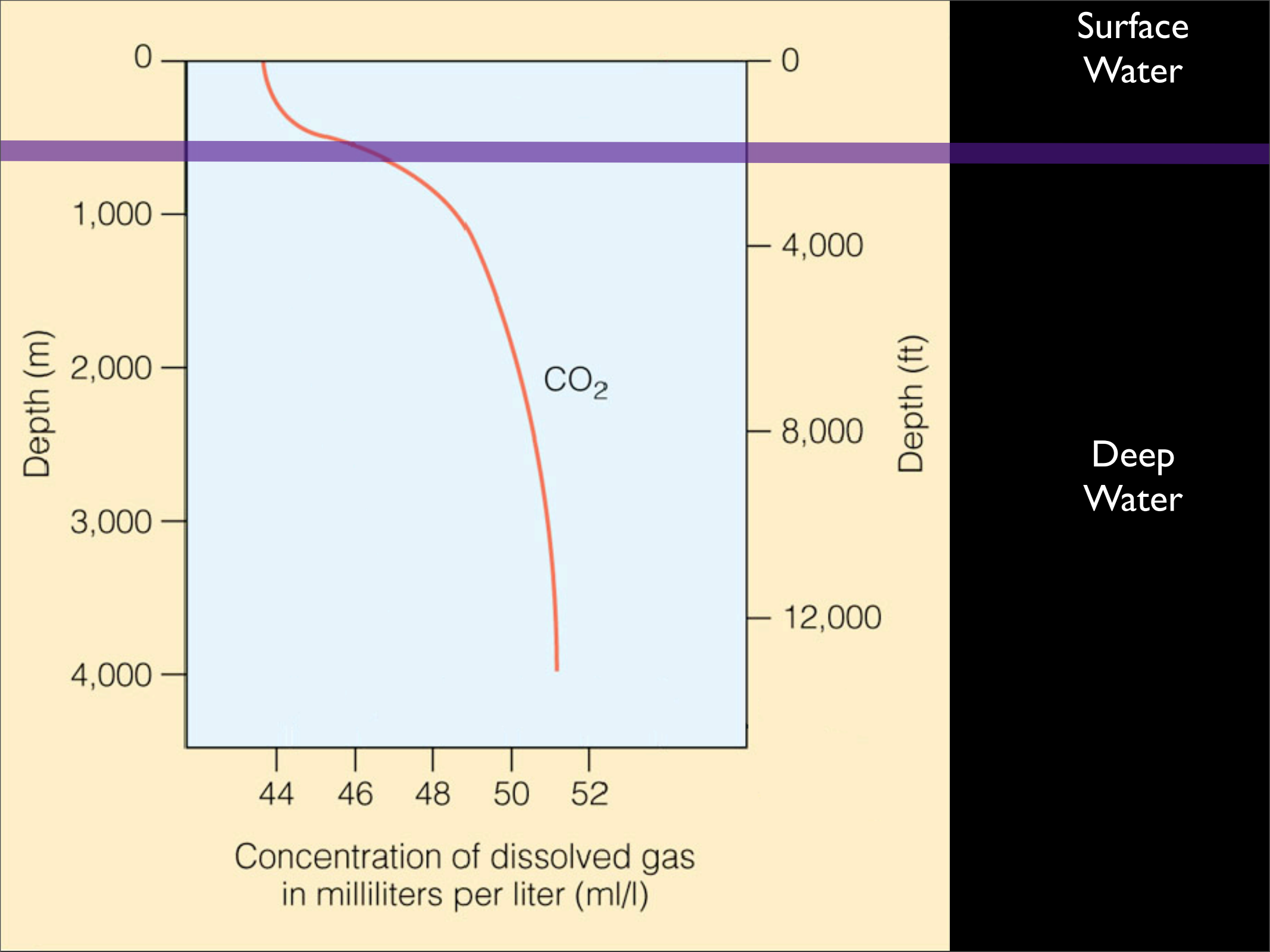
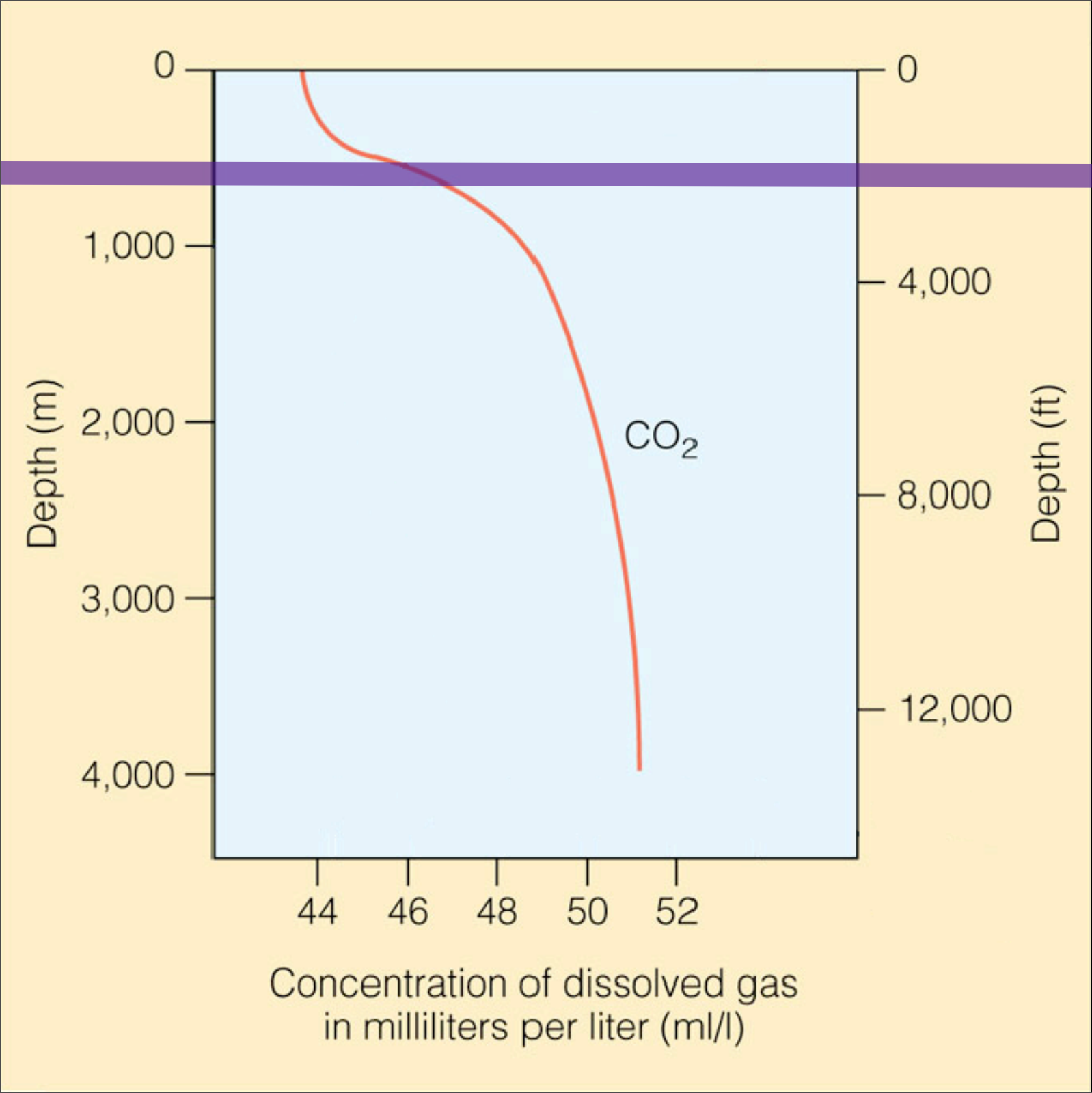

Surface Water
0
1,000
2,000
3,000
4,000
Depth (m)
0
4,000
8,000
12,000
Depth (ft)
CO_2
44
46
48
50
52
Concentration of dissolved gas in milliliters per liter (ml/l)


Surface Water
Deep Water
0
1,000
2,000
3,000
4,000
Depth (m)
0
4,000
8,000
12,000
Depth (ft)
CO_2
44
46
48
50
52
Concentration of dissolved gas in milliliters per liter (ml/l)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2,000
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4,000
Depth (m)
0
4,000
8,000
12,000
Depth (ft)
CO_2
44
46
48
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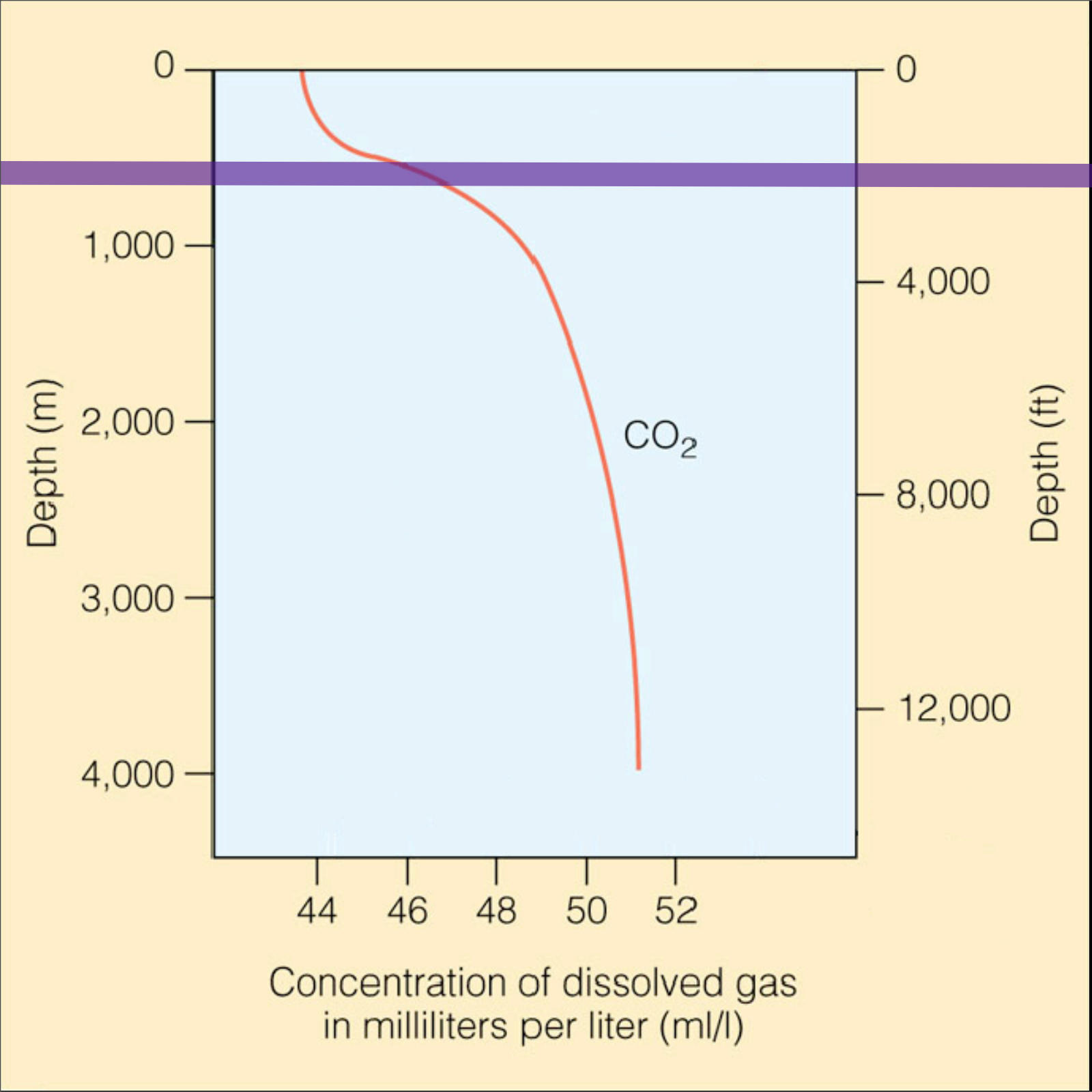
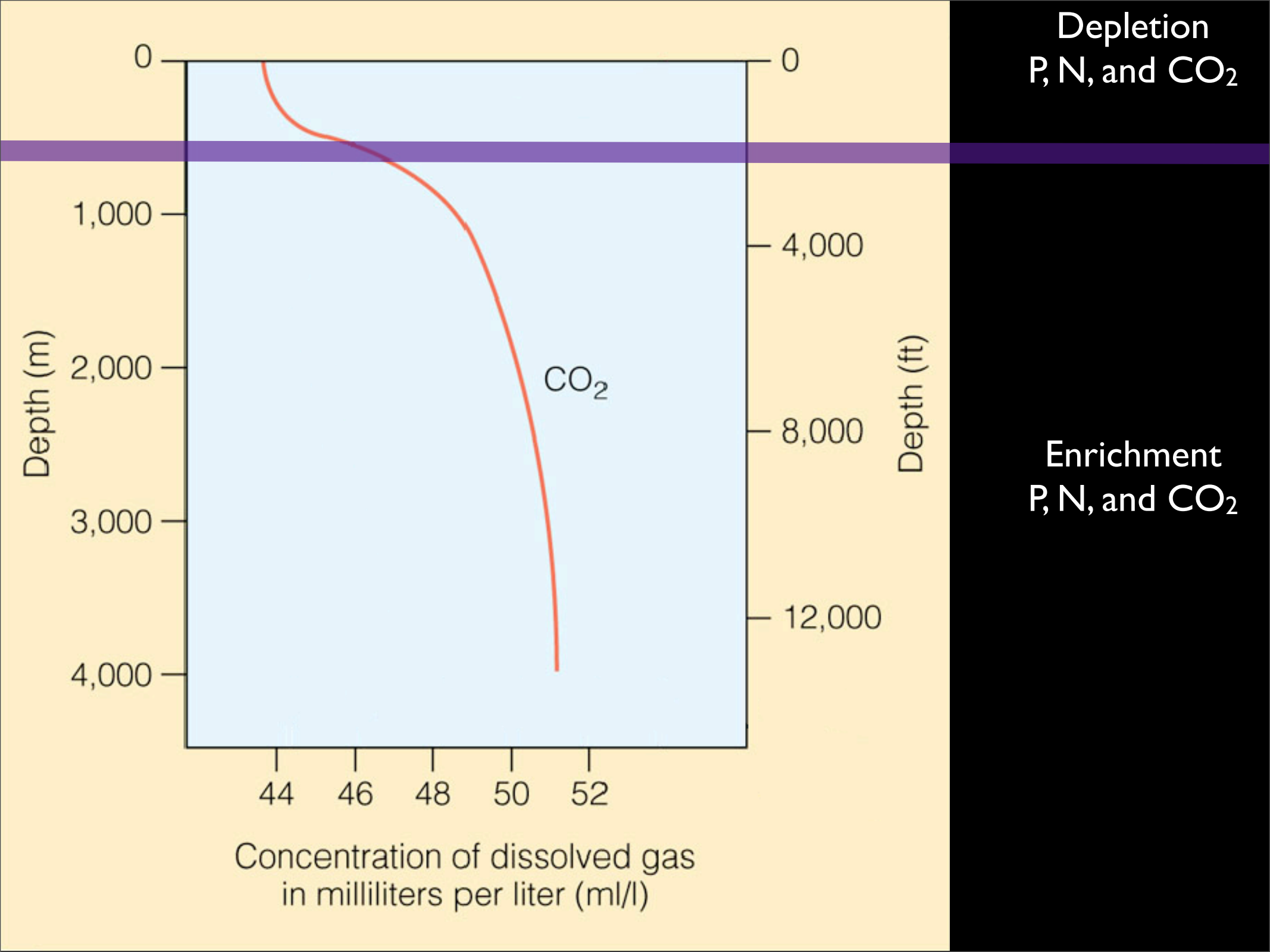
Concentration of dissolved gas
in milliliters per liter (ml/l)

Depletion
P, N, and CO_2




Depletion
P, N, and CO_2
Enrichment
P, N, and CO_2
0
1,000
2,000
3,000
4,000
Depth (m)
0
4,000
8,000
12,000
Depth (ft)
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Concentration of dissolved gas
in milliliters per liter (ml/l)

Vertical Variation

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- Two primary biological process:
  - Photosynthesis

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- Two primary biological process:
  - Photosynthesis
  - Respiration

Photosynthesis

Photosynthesis

- $CO_2 + H_2O = CH_2O + O_2$

Photosynthesis

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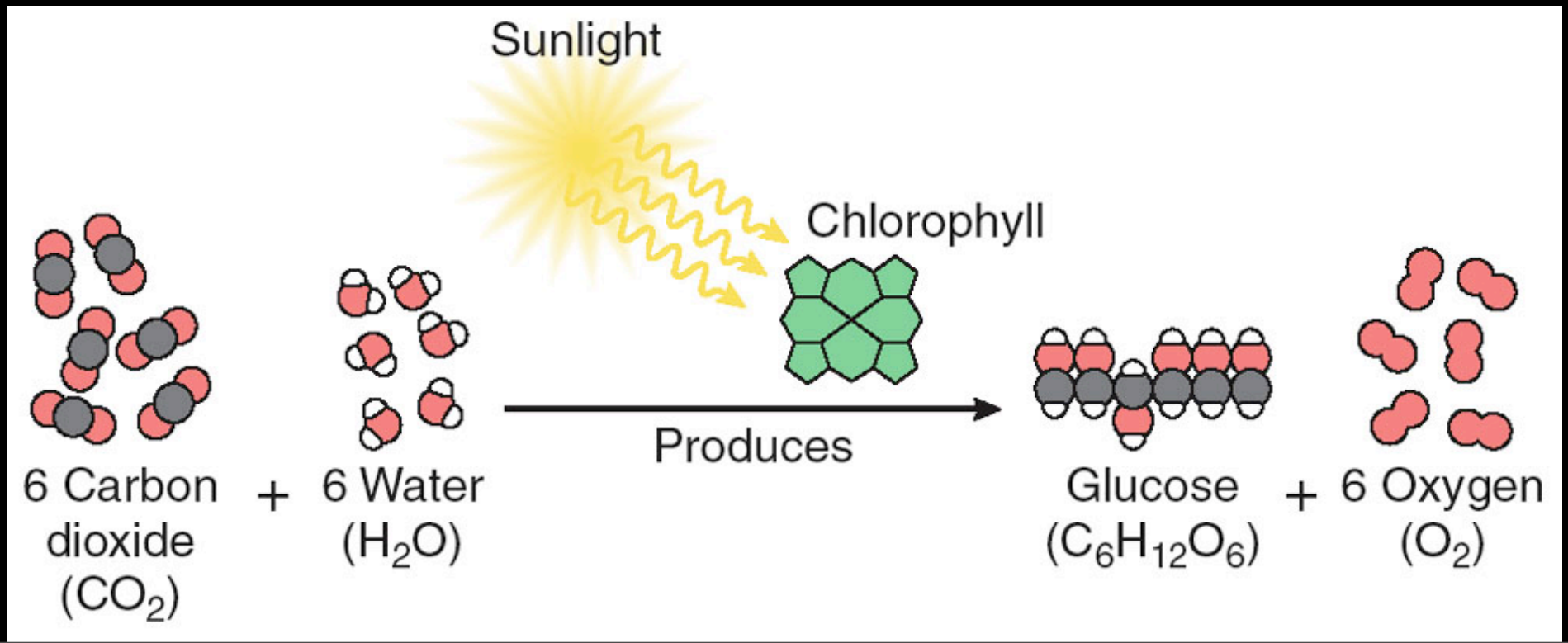

Photosynthesis

Photosynthesis

- (P, N, etc) + CO_2 + H_2O = CH_2O(P, N, etc) + O_2

Photosynthesis

- (P, N, etc) + CO_2 + H_2O = CH_2O(P, N, etc) + O_2
- Consumes P, N, and CO_2

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- (P, N, etc) + CO_2 + H_2O = CH_2O(P, N, etc) + O_2
- Consumes P, N, and CO_2
- Releases O_2

Respiration

Respiration

- $CH_2O(P, N, etc) + O_2 = (P, N, etc) + CO_2 + H_2O$

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Respiration

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- Releases P, N, and CO_2

P, N, & CO_2 Variations

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- Plants live in surface waters and incorporate constituents used during photosynthesis

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P, N, & CO_2 Variations

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- Photosynthesis dominates in surface waters
- P, N, and CO_2 are depleted

P, N, & CO_2 Variations

- Plants live in surface waters and incorporate constituents used during photosynthesis
- Photosynthesis dominates in surface waters
- P, N, and CO_2 are depleted
- Surface water is depleted in the constituents consumed during photosynthesis

P, N, & CO_2 Variations

P, N, & CO_2 Variations

- Organic matter sinks into deeper water

P, N, & CO_2 Variations

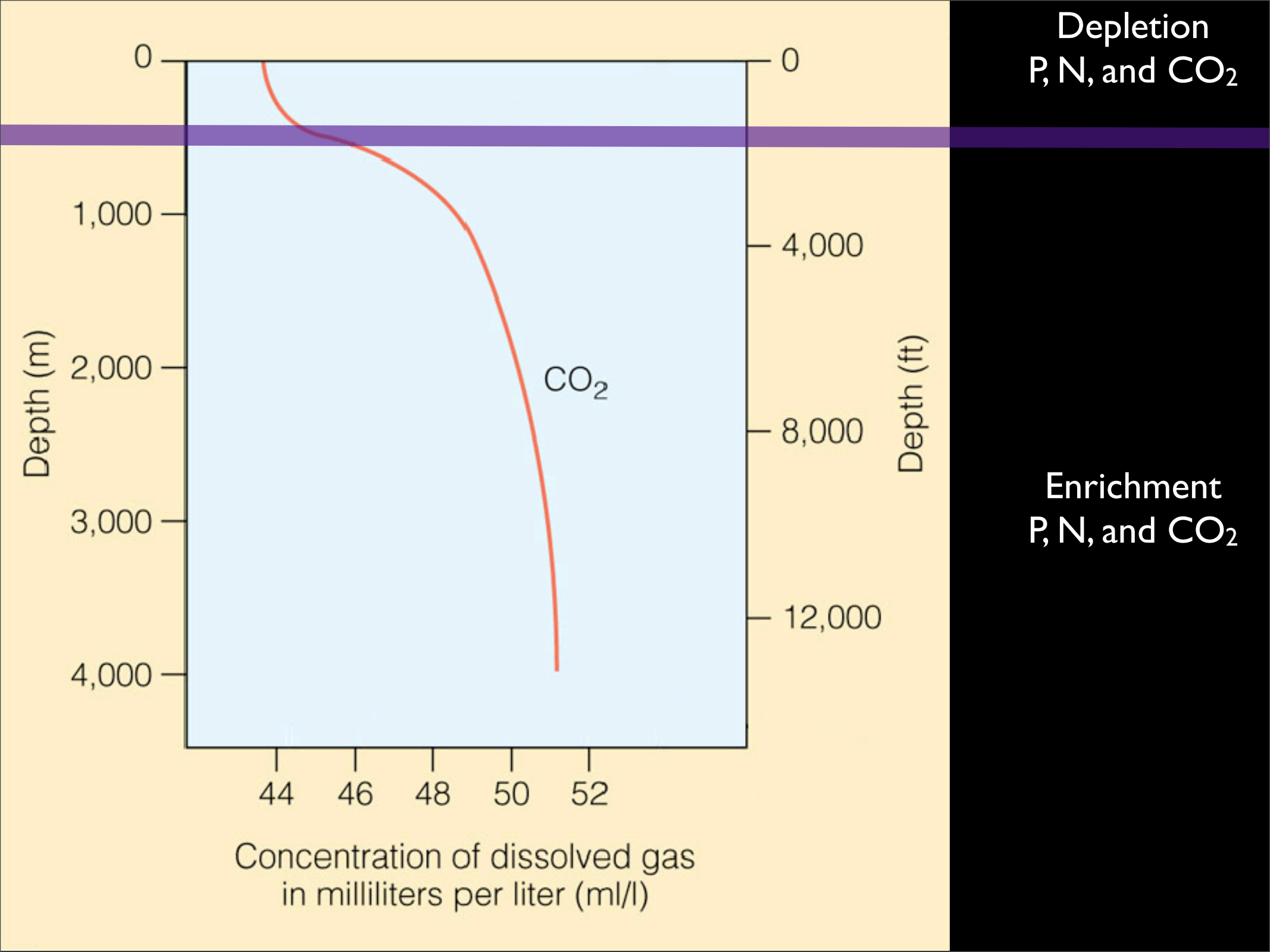
- Organic matter sinks into deeper water
- Where organic matter is respired

P, N, & CO_2 Variations

- Organic matter sinks into deeper water
- Where organic matter is respired
- Only respiration occurs in deep water

P, N, & CO_2 Variations

- Organic matter sinks into deeper water
- Where organic matter is respired
- Only respiration occurs in deep water
- Deep water is enriched in the constituents released during respiration


Depletion
P, N, and CO_2
Enrichment
P, N, and CO_2
0
1,000
2,000
3,000
4,000
Depth (m)
0
4,000
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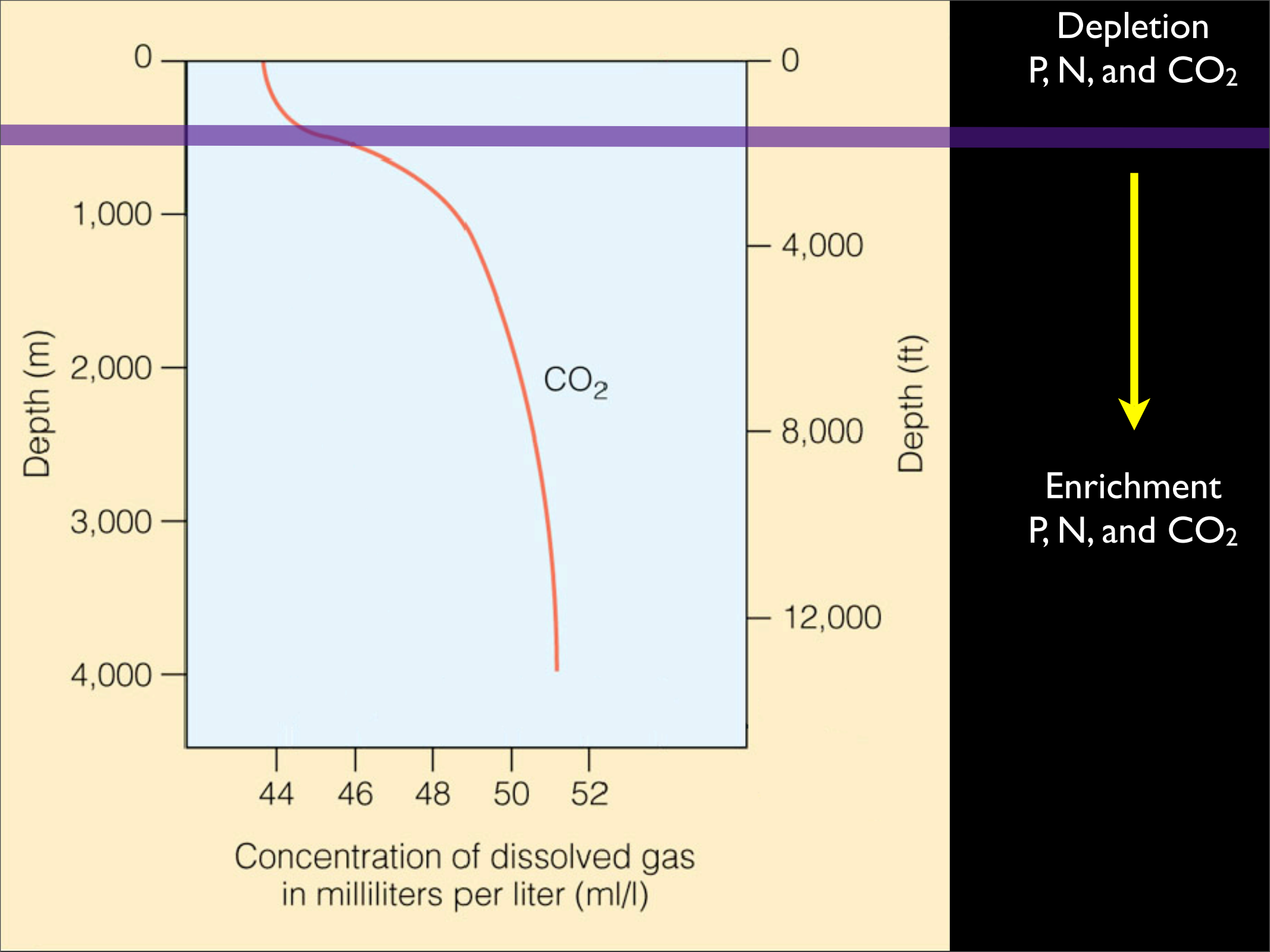
Depletion
P, N, and CO_2
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P, N, and CO_2
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4,000
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Concentration of dissolved gas
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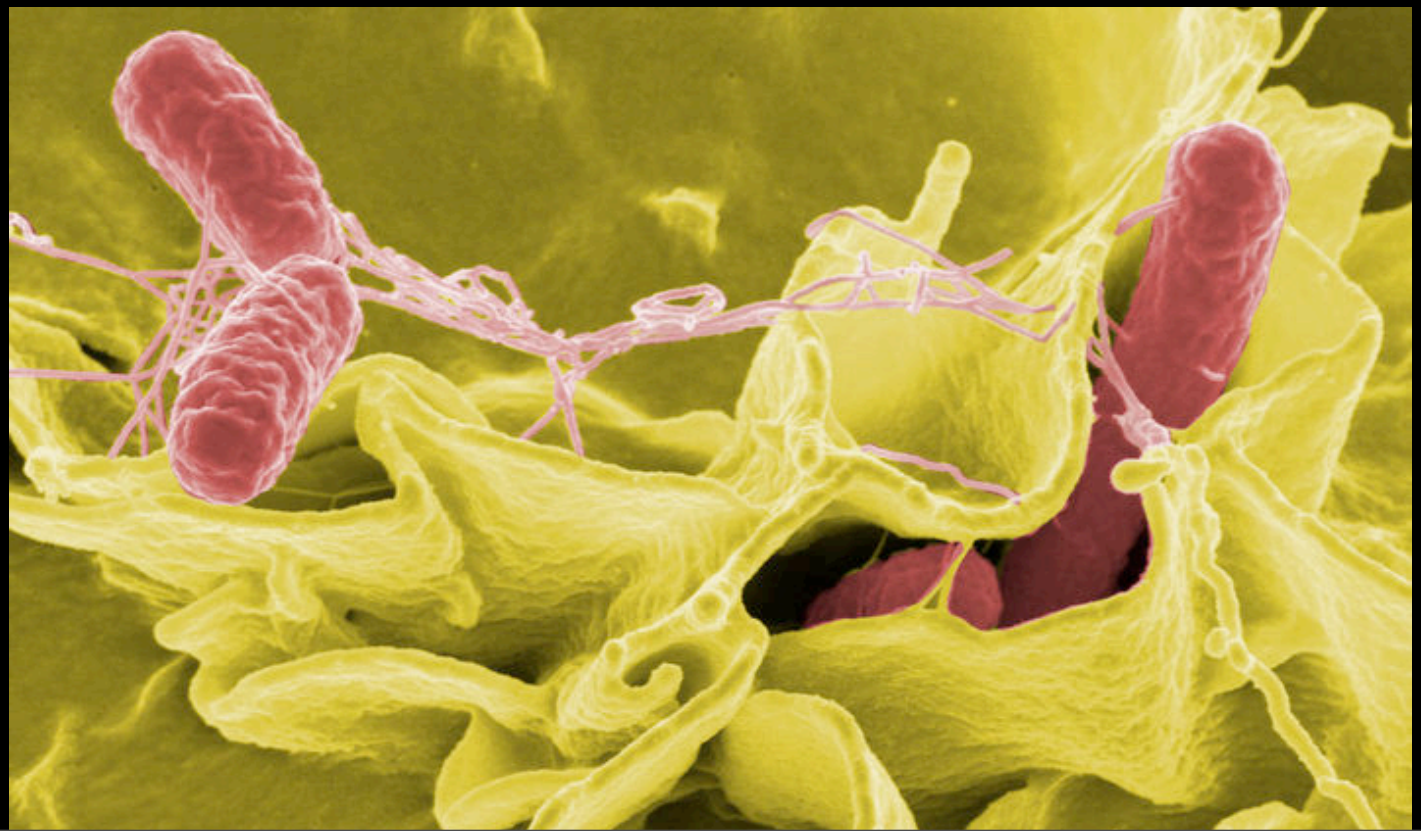
Primary Decomposers

Primary Decomposers

- Bacteria are the primary decomposers



Oxygen Variation

Oxygen Variation

- O_2 is an exception to the primary pattern

Oxygen Variation

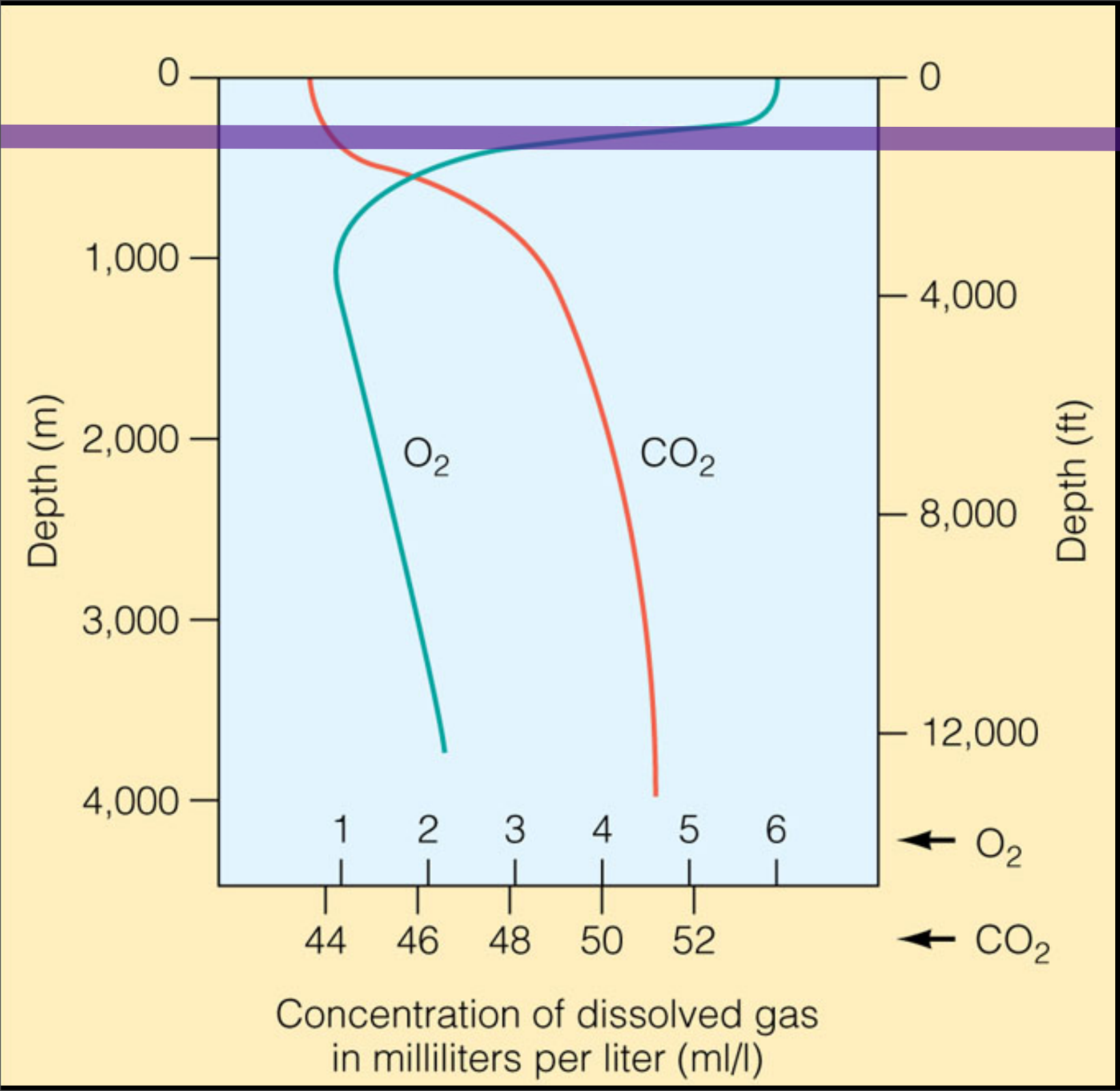
- O_2 is an exception to the primary pattern
- O_2 is
  - Enriched in surface waters
  - Depleted at depth

Oxygen Variation

- O_2 is an exception to the primary pattern
- O_2 is
  - Enriched in surface waters
  - Depleted at depth
- Enriched during photosynthesis

Oxygen Variation

- O_2 is an exception to the primary pattern
- O_2 is
  - Enriched in surface waters
  - Depleted at depth
- Enriched during photosynthesis
- Depleted during respiration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Depth (m)
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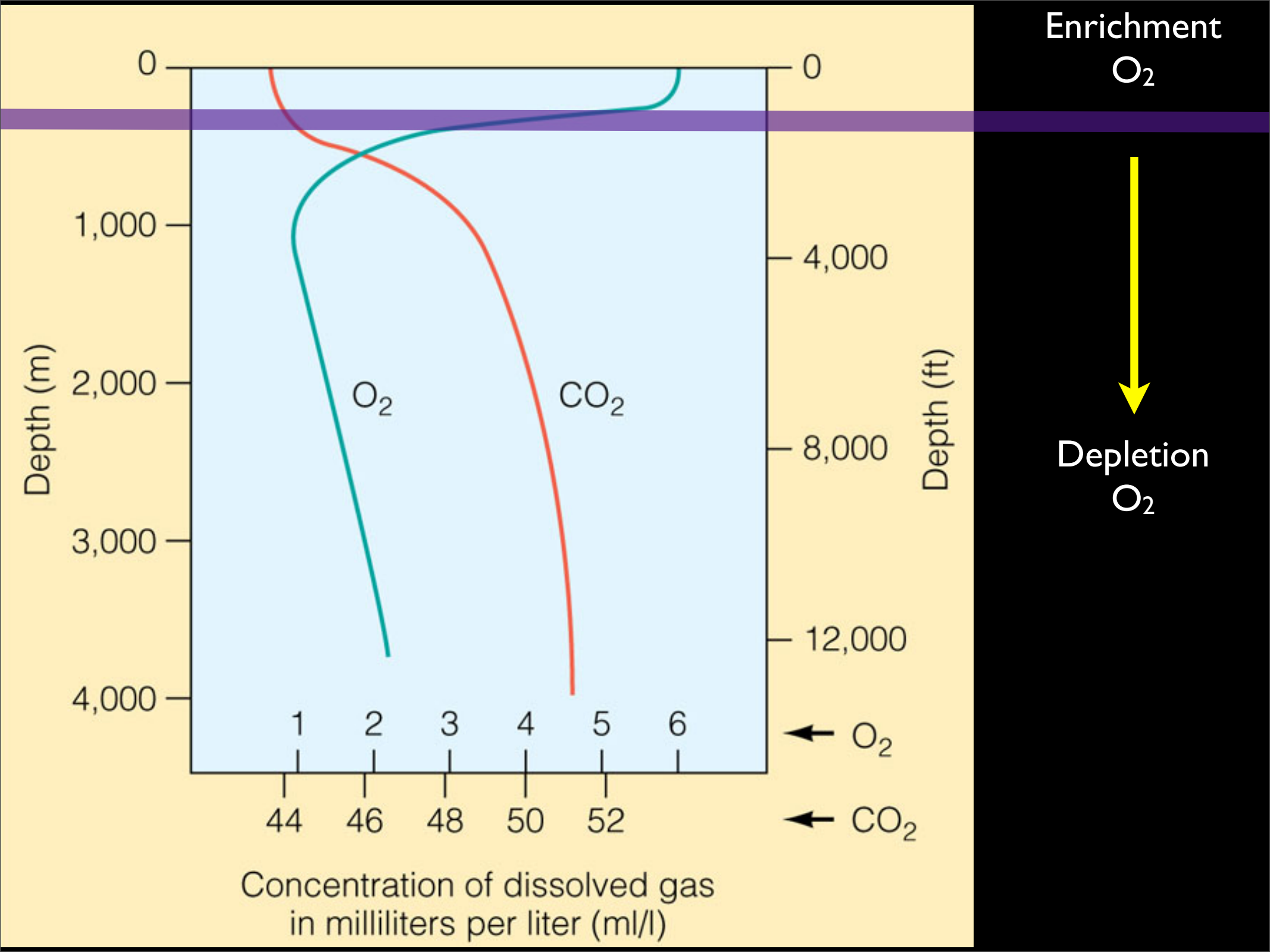
8,000
12,000
Depth (ft)
O_2
CO_2
1
2
3
4
5
6
44
46
48
50
52
O_2
CO_2
Concentration of dissolved gas
in milliliters per liter (ml/l)


Enrichment
O_2
Depletion
O_2
0
1,000
2,000
3,000
4,000
Depth (m)
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4,000
8,000
12,000
Depth (ft)
O_2
CO_2
1
2
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O_2
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CO_2
Concentration of dissolved gas
in milliliters per liter (ml/l)

Horizontal Variations:

Minor Constituents, Trace Elements, and Gases

Horizontal Variations:
Minor Constituents, Trace Elements, and Gases

- Horizontal variations occur in deep water

Horizontal Variations:
Minor Constituents, Trace Elements, and Gases

- Horizontal variations occur in deep water
- Major constituents concentrations are constant

Horizontal Variations:
Minor Constituents, Trace Elements, and Gases

- Horizontal variations occur in deep water
- Major constituents concentrations are constant
- See significant variations in minor constituents, trace elements, and gases

Horizontal Variations:

Minor Constituents, Trace Elements, and Gases

Horizontal Variations:
Minor Constituents, Trace Elements, and Gases

- Primary horizontal variation pattern:

Horizontal Variations:
Minor Constituents, Trace Elements, and Gases

- Primary horizontal variation pattern:
  - Lowest concentrations in the deep Atlantic

Horizontal Variations:
Minor Constituents, Trace Elements, and Gases

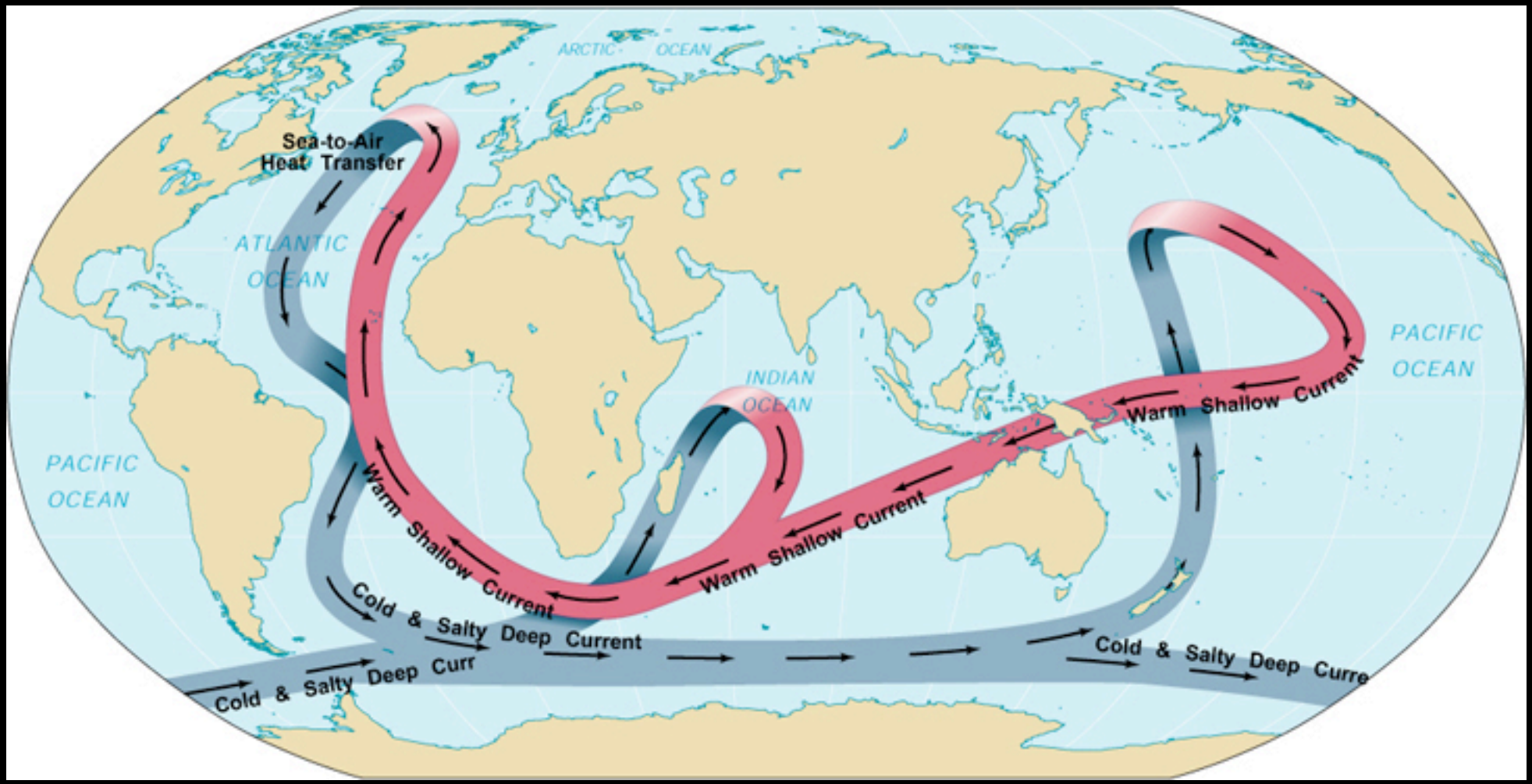
- Primary horizontal variation pattern:
  - Lowest concentrations in the deep Atlantic
  - Higher in the deep Indian

Horizontal Variations:
Minor Constituents, Trace Elements, and Gases

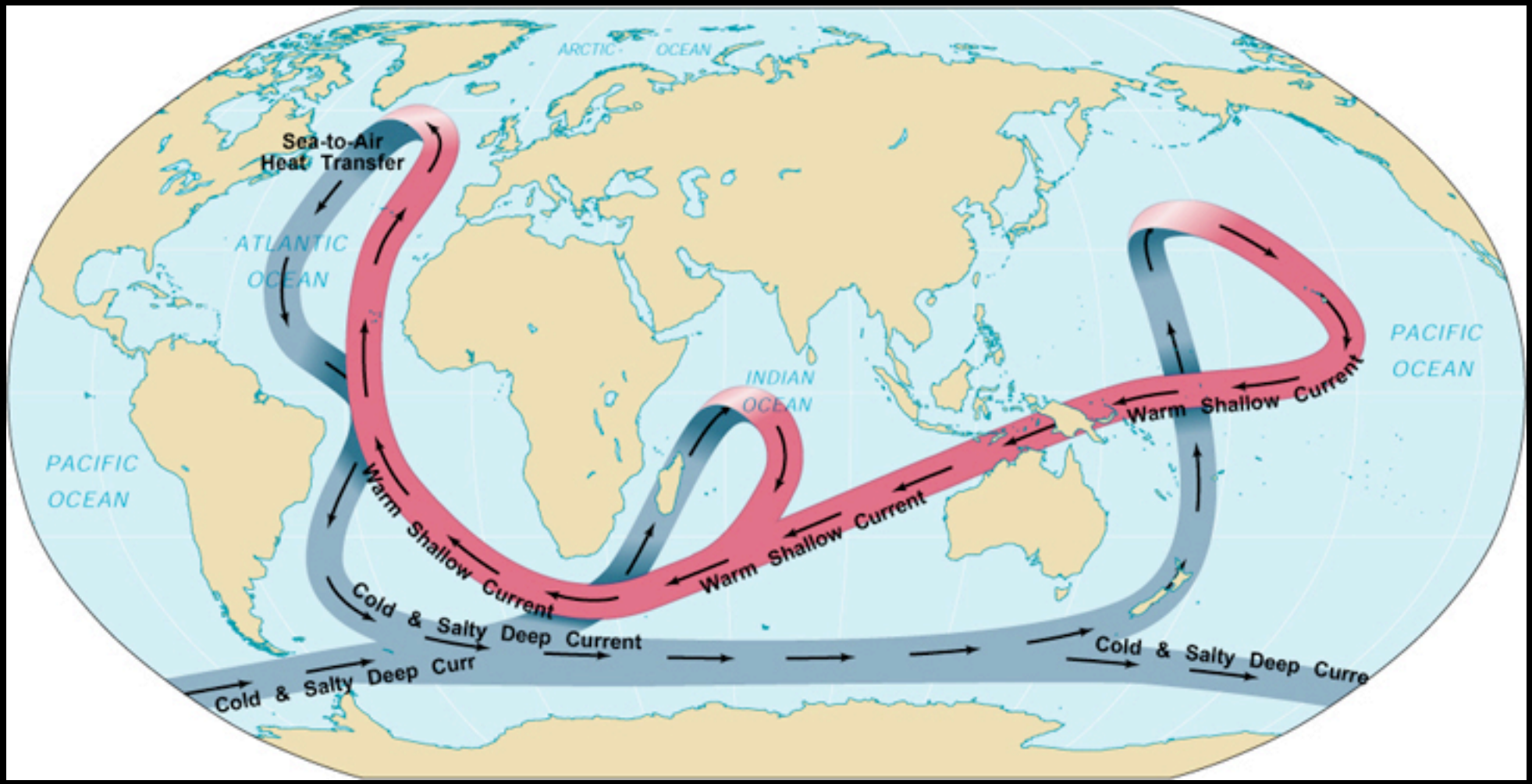
- Primary horizontal variation pattern:
  - Lowest concentrations in the deep Atlantic
  - Higher in the deep Indian
  - Highest in the deep Pacific

Deep-Ocean Current

Deep-Ocean Current

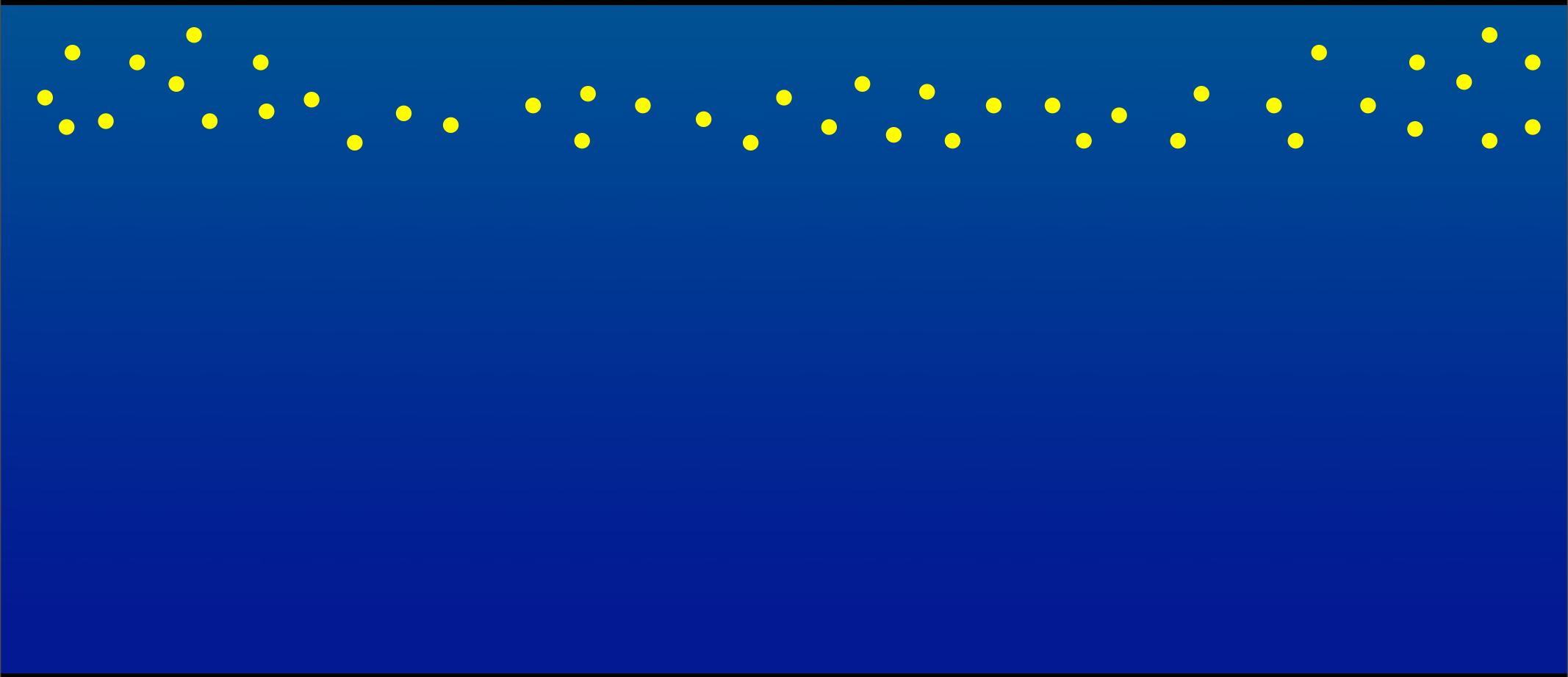


Deep-Ocean Current



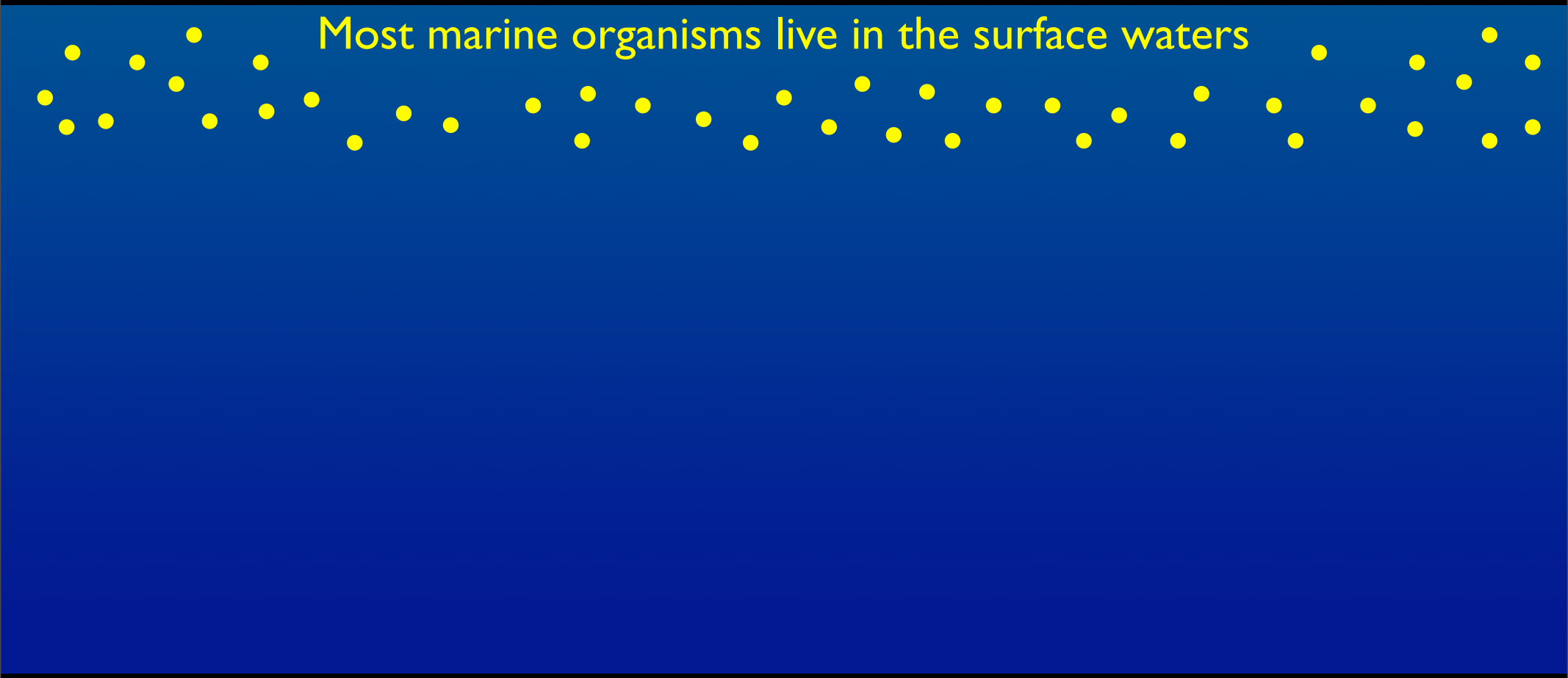
Atlantic → Indian → Pacific

Horizontal Variations



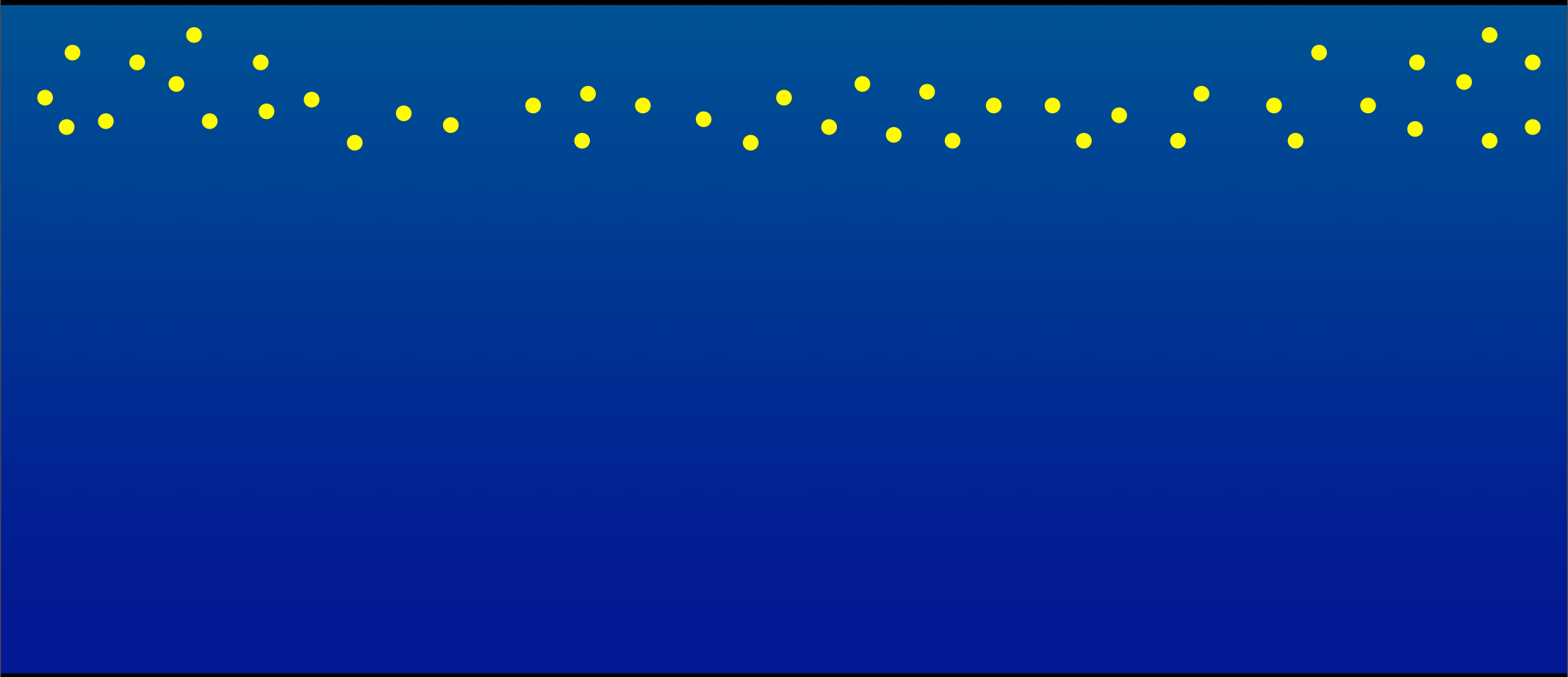
Atlantic Indian Pacific

Horizontal Variations



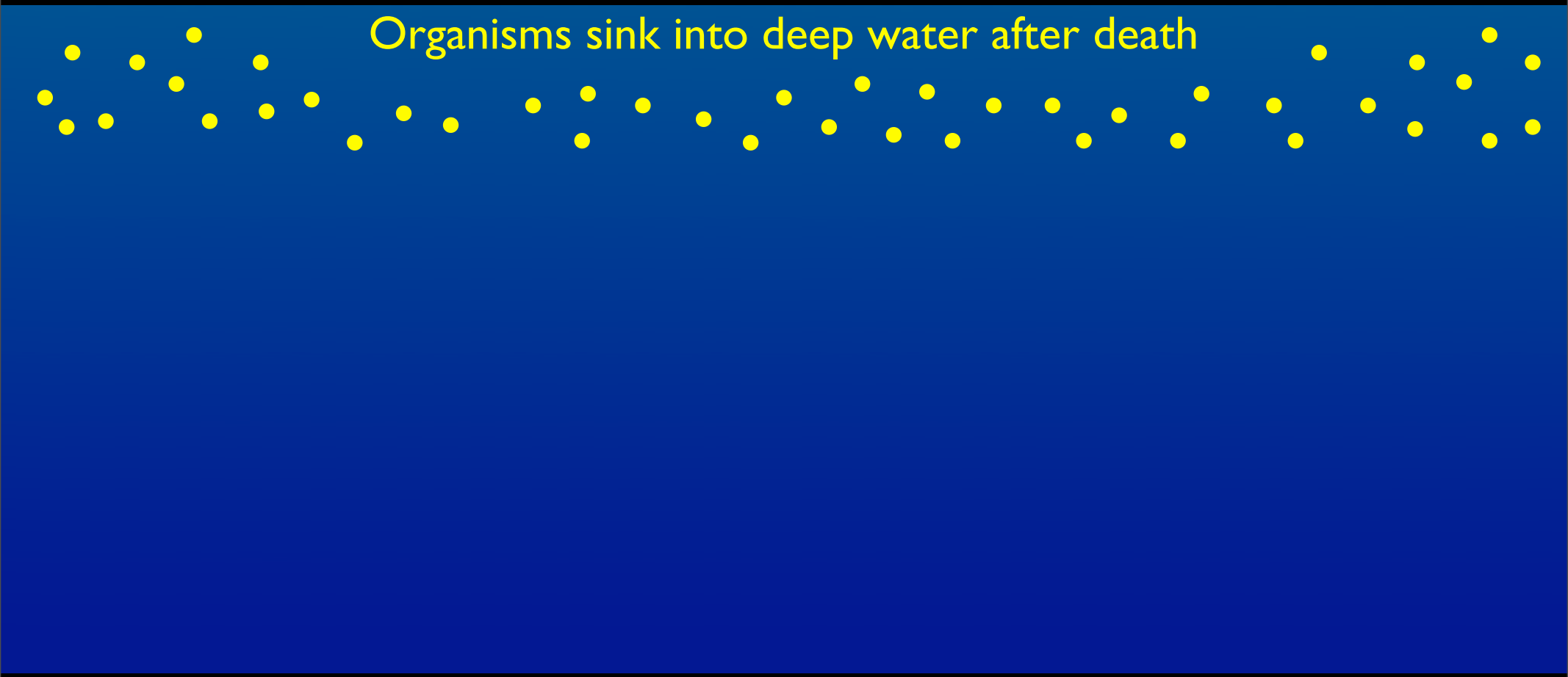
Atlantic Indian Pacific

Horizontal Variations



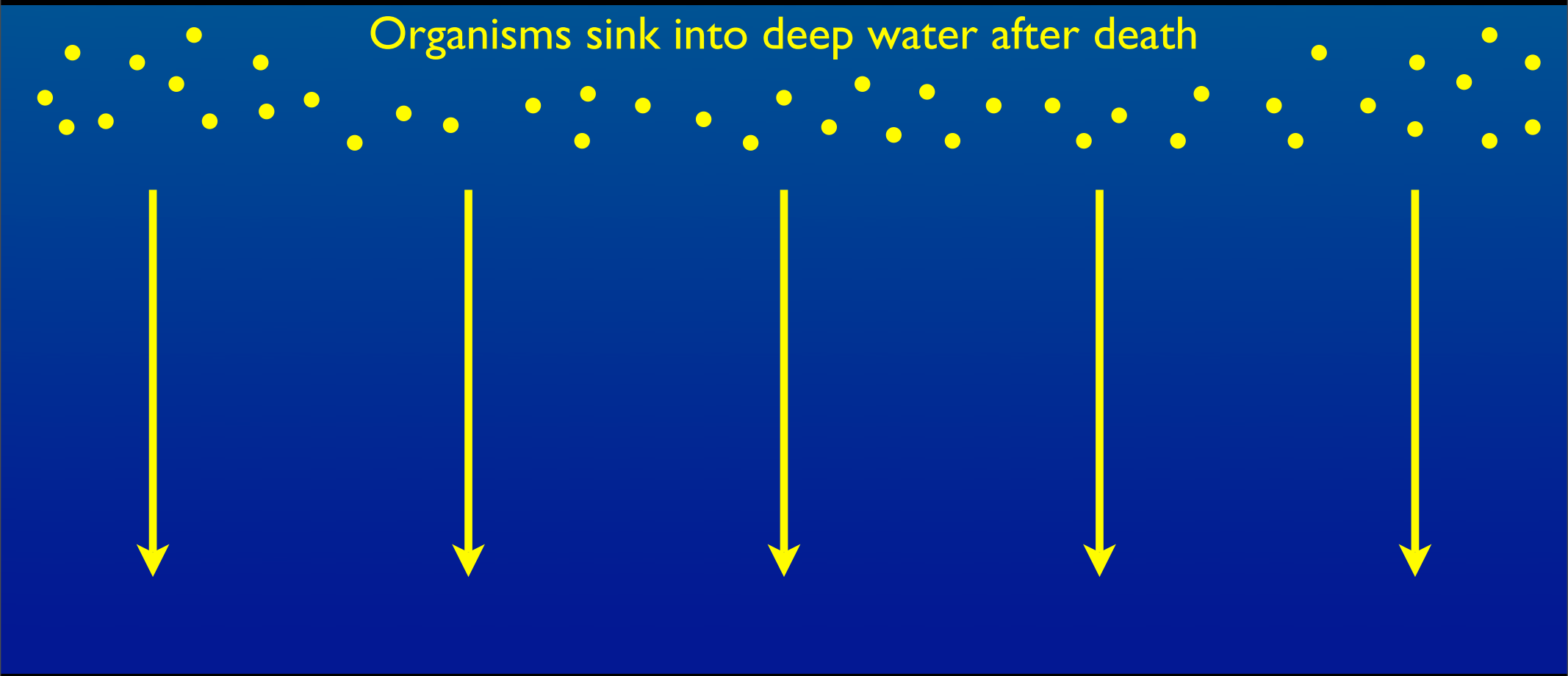
Atlantic Indian Pacific

Horizontal Variations



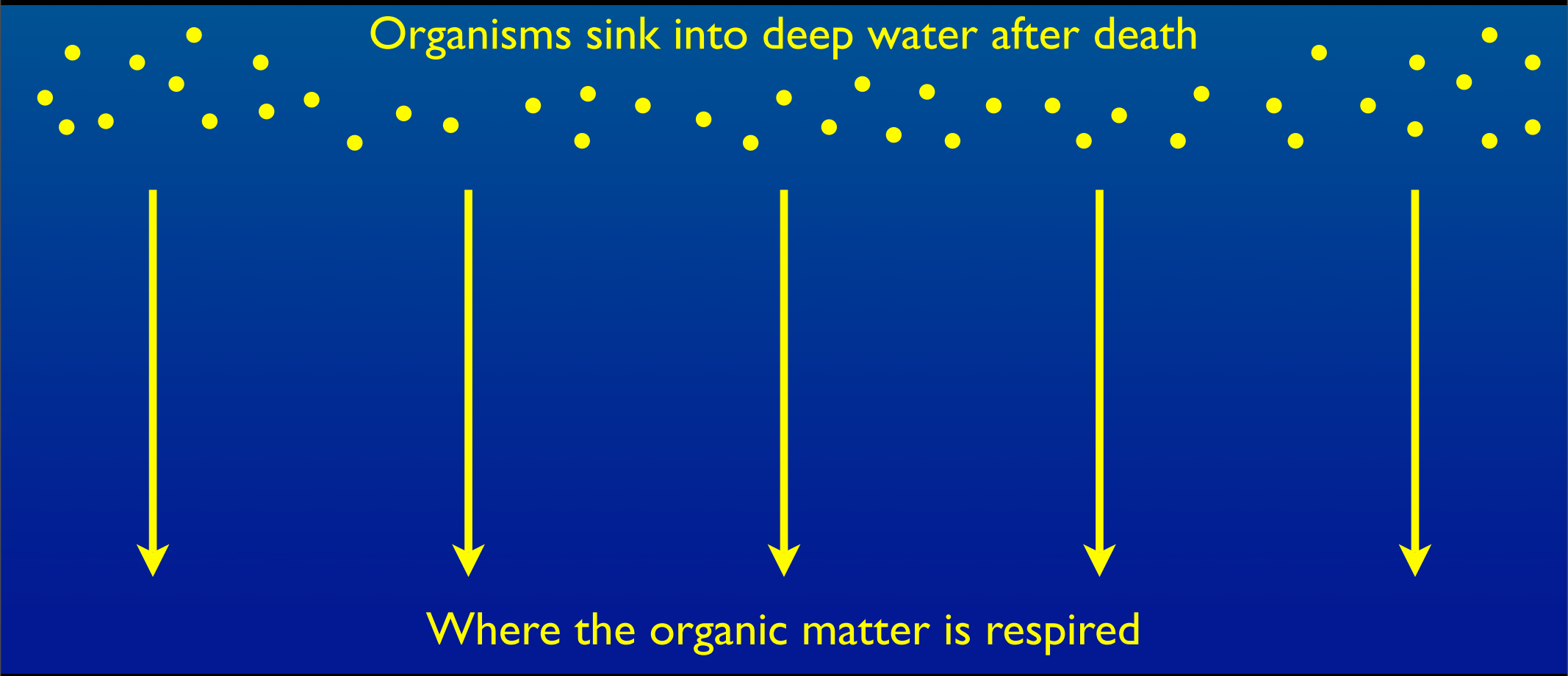
Atlantic Indian Pacific

Horizontal Variations



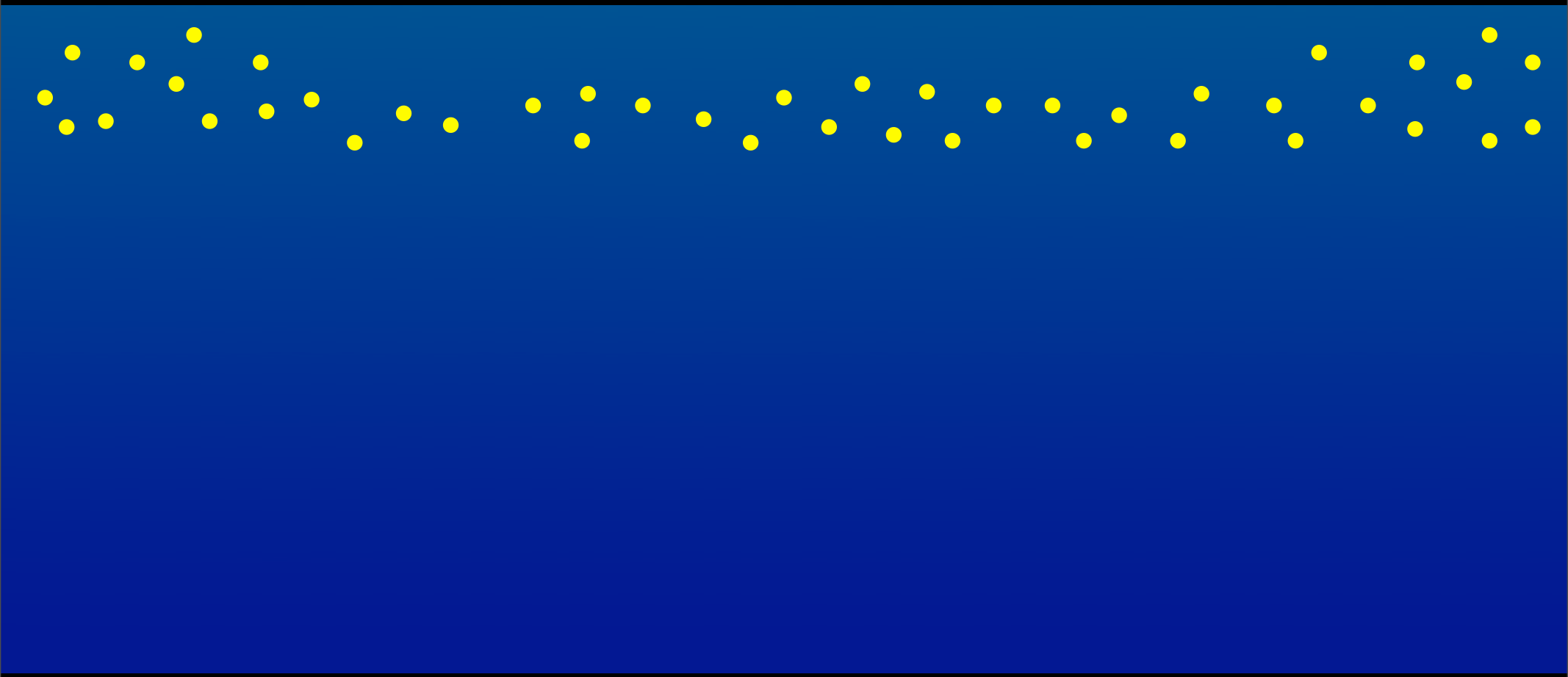
Atlantic Indian Pacific

Horizontal Variations



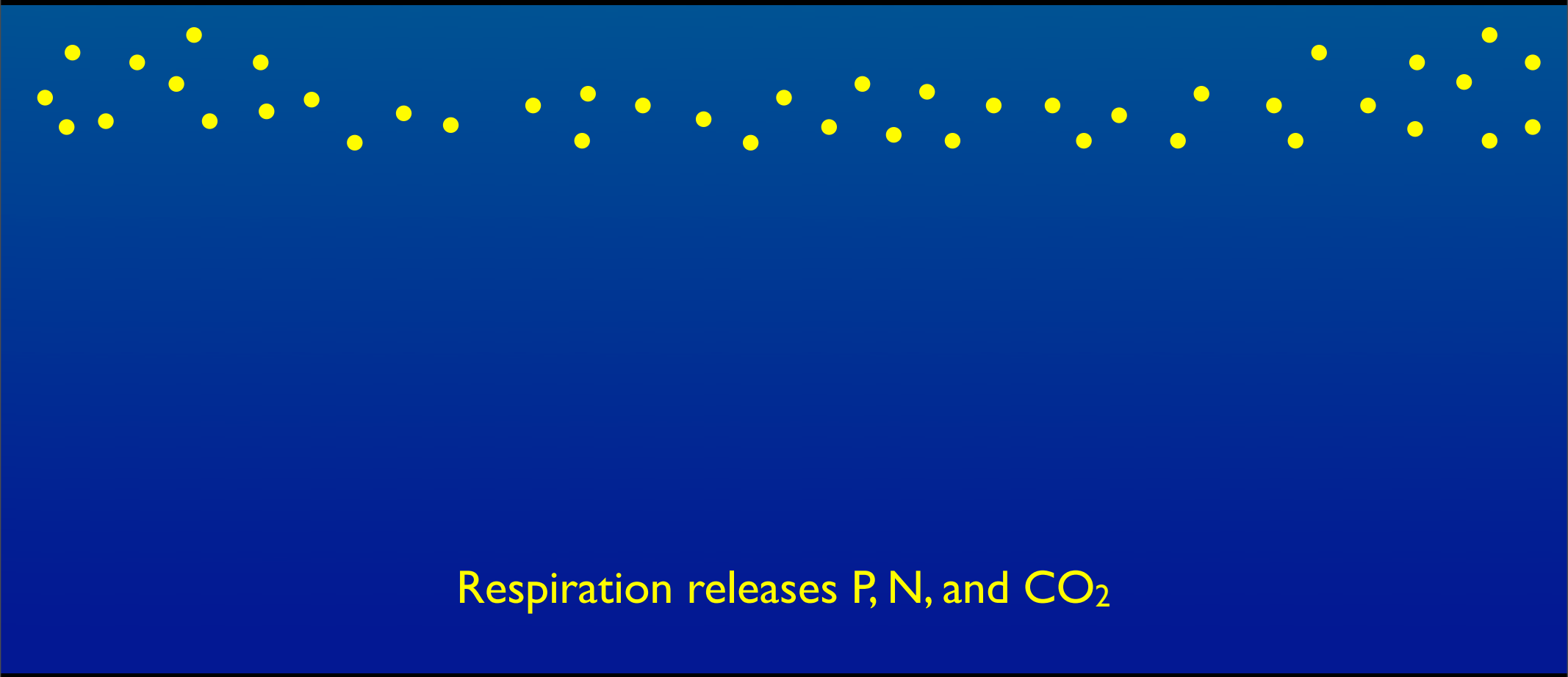
Atlantic Indian Pacific

Horizontal Variations



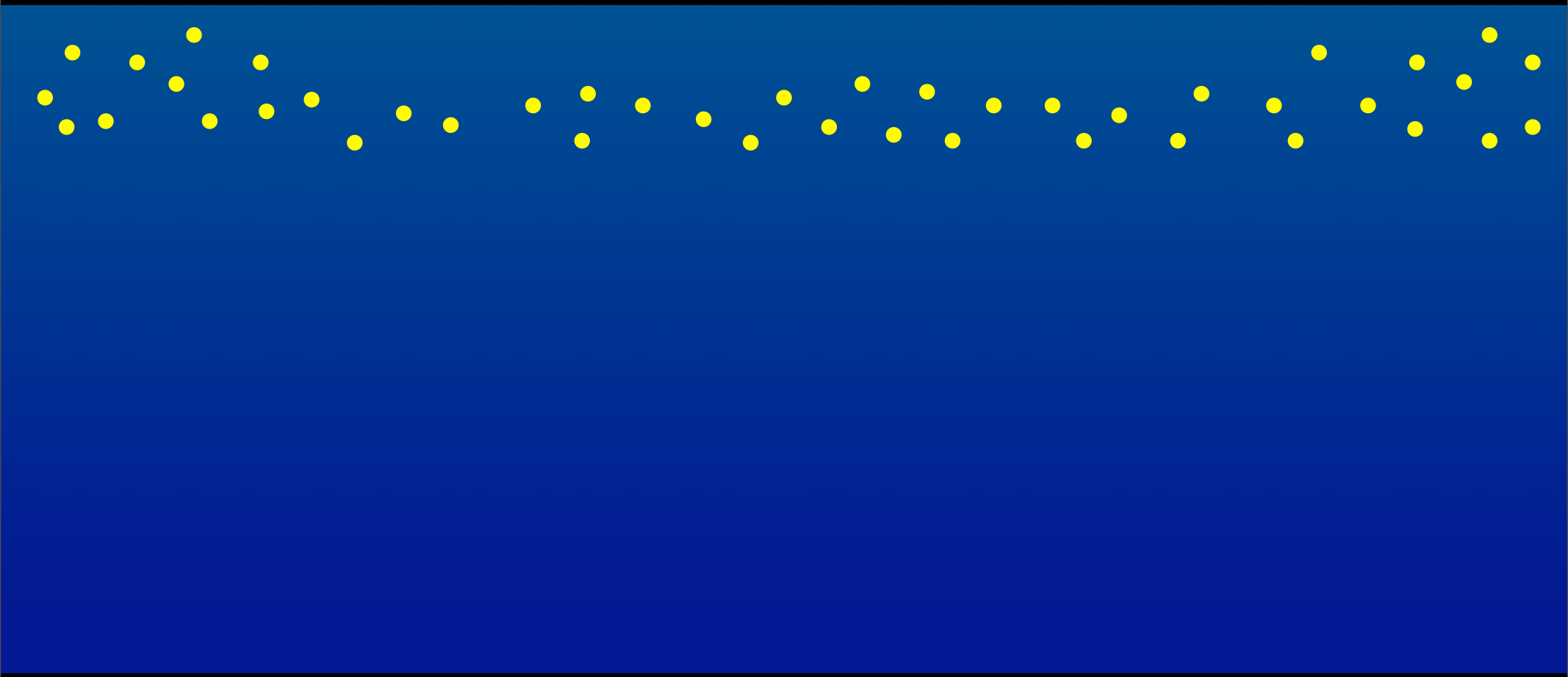
Atlantic Indian Pacific

Horizontal Variations



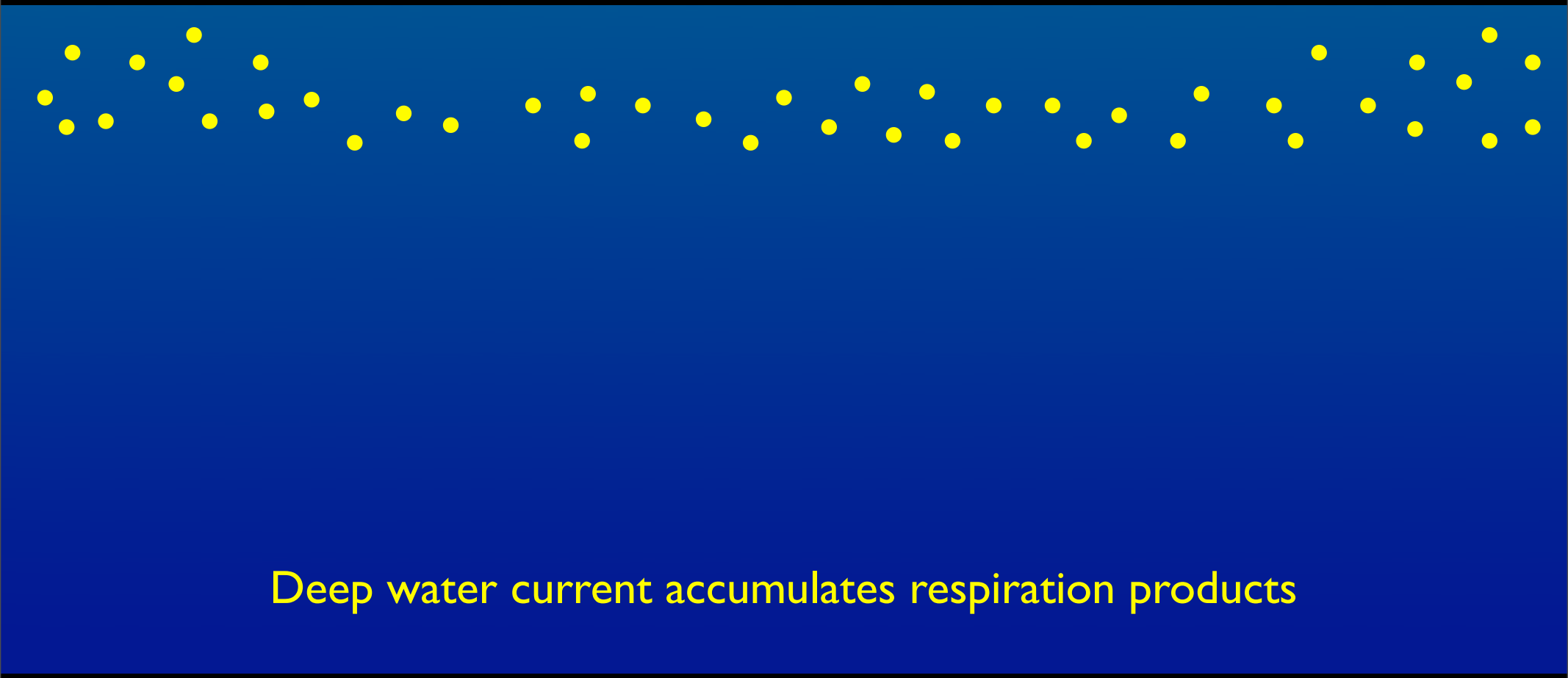
Atlantic Indian Pacific

Horizontal Variations

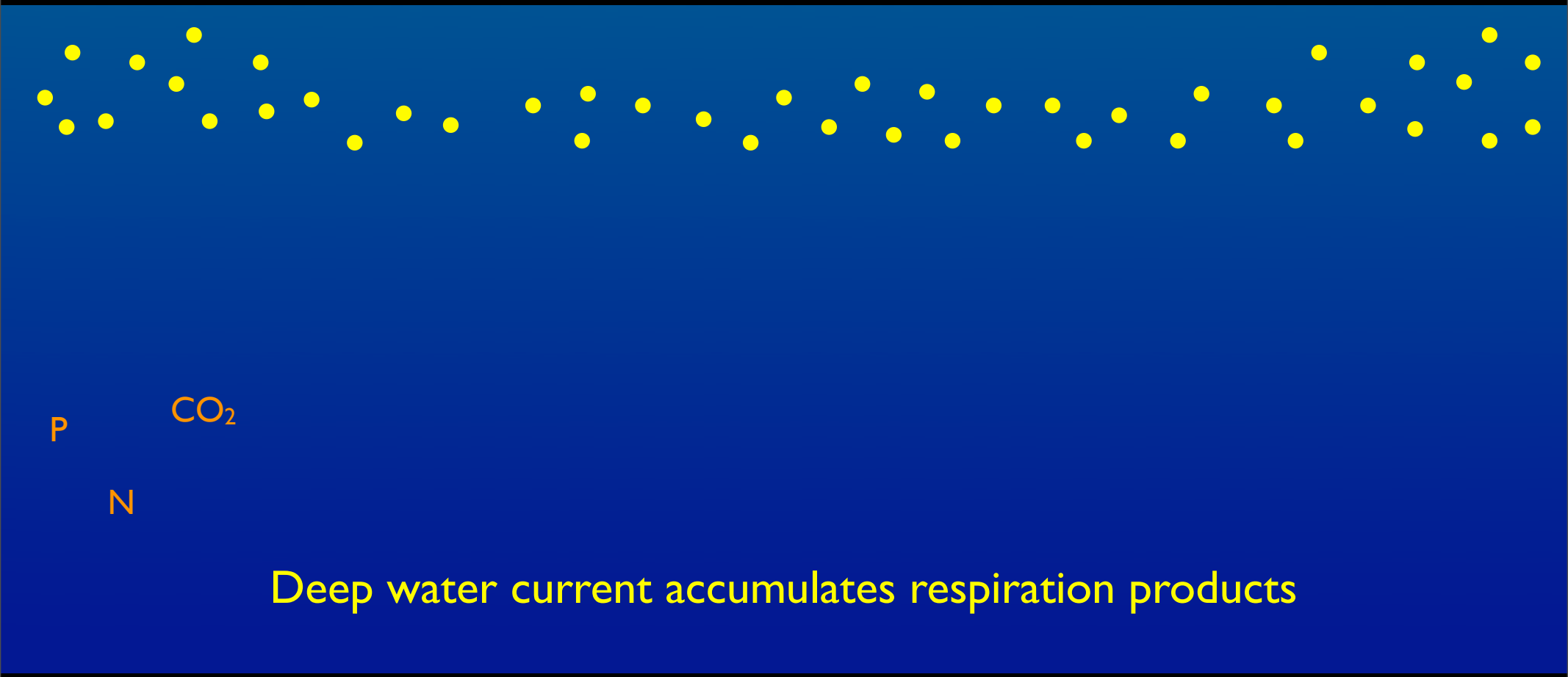


Atlantic Indian Pacific

Horizontal Variations



Horizontal Variations



Atlantic Indian Pacific

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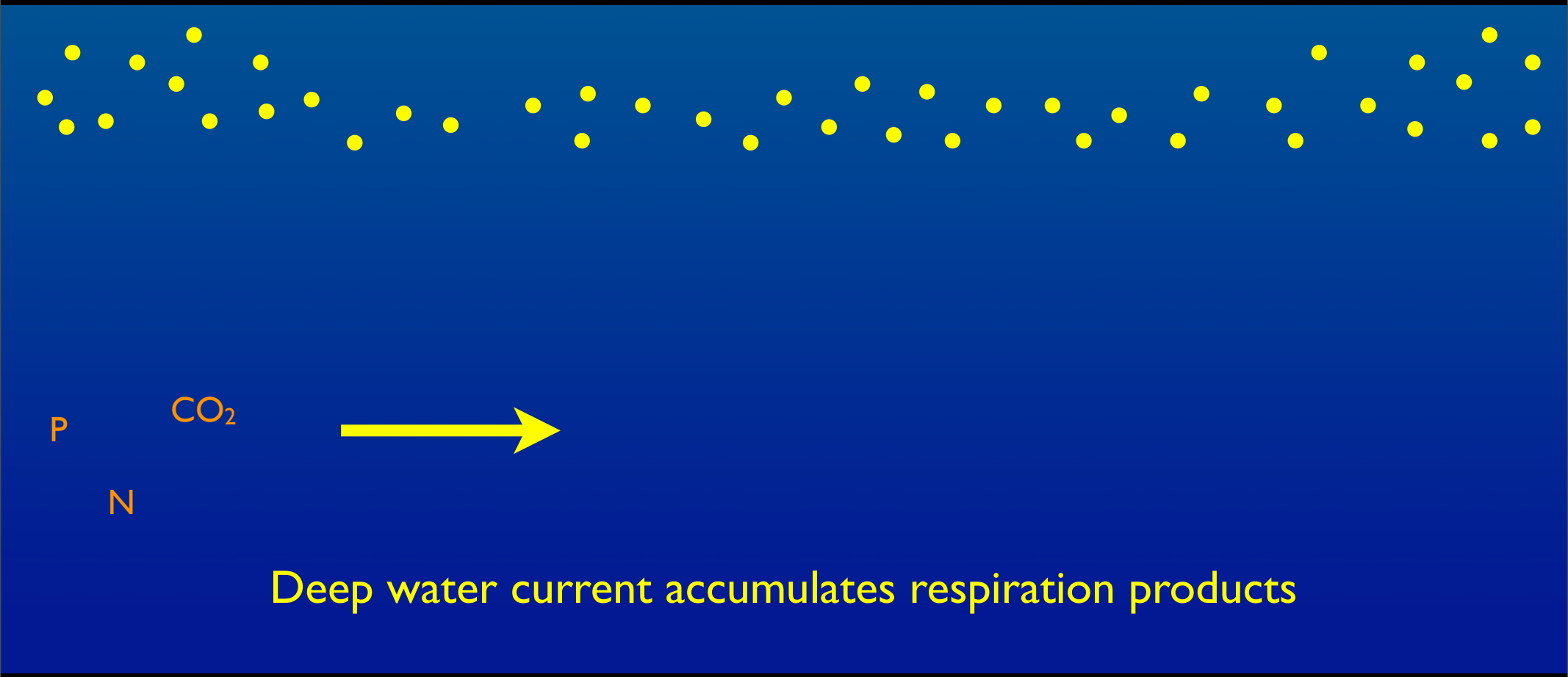
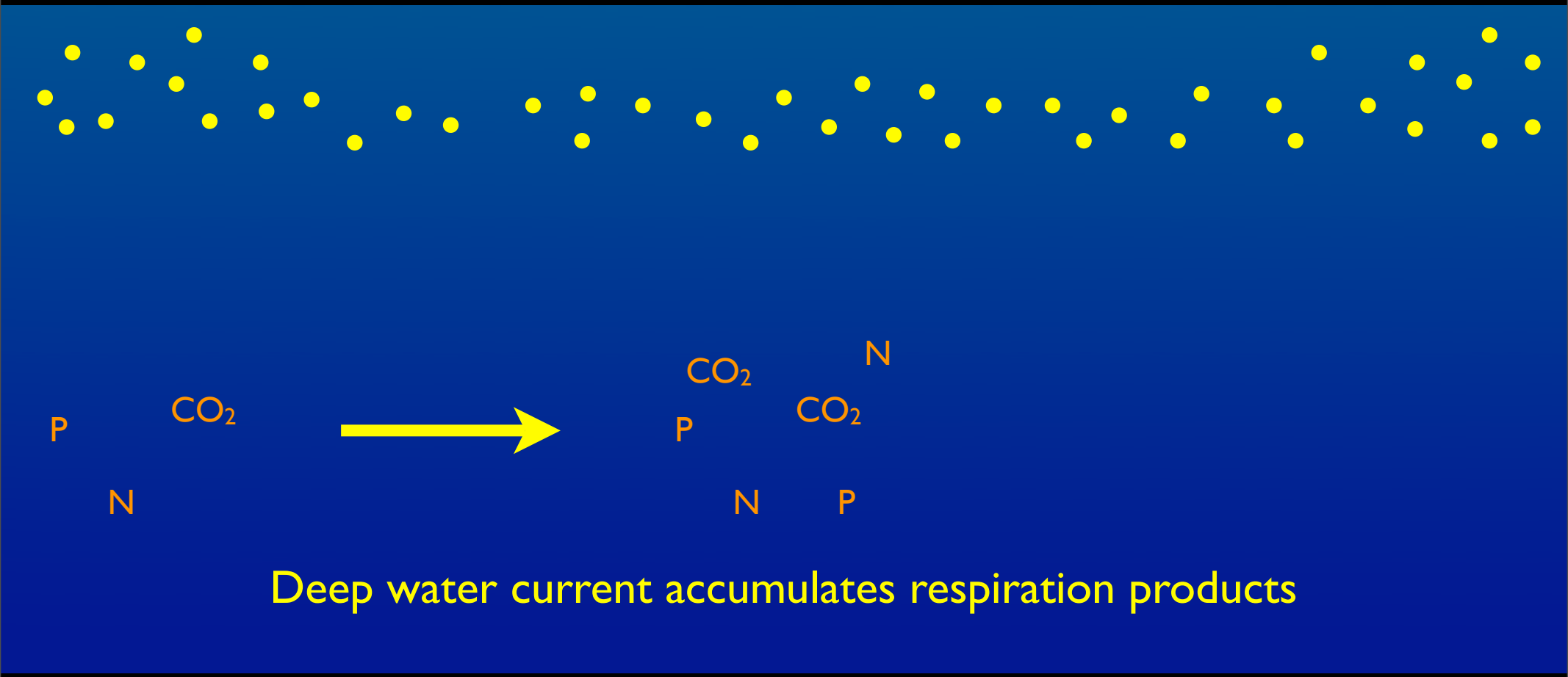


Atlantic Indian Pacific

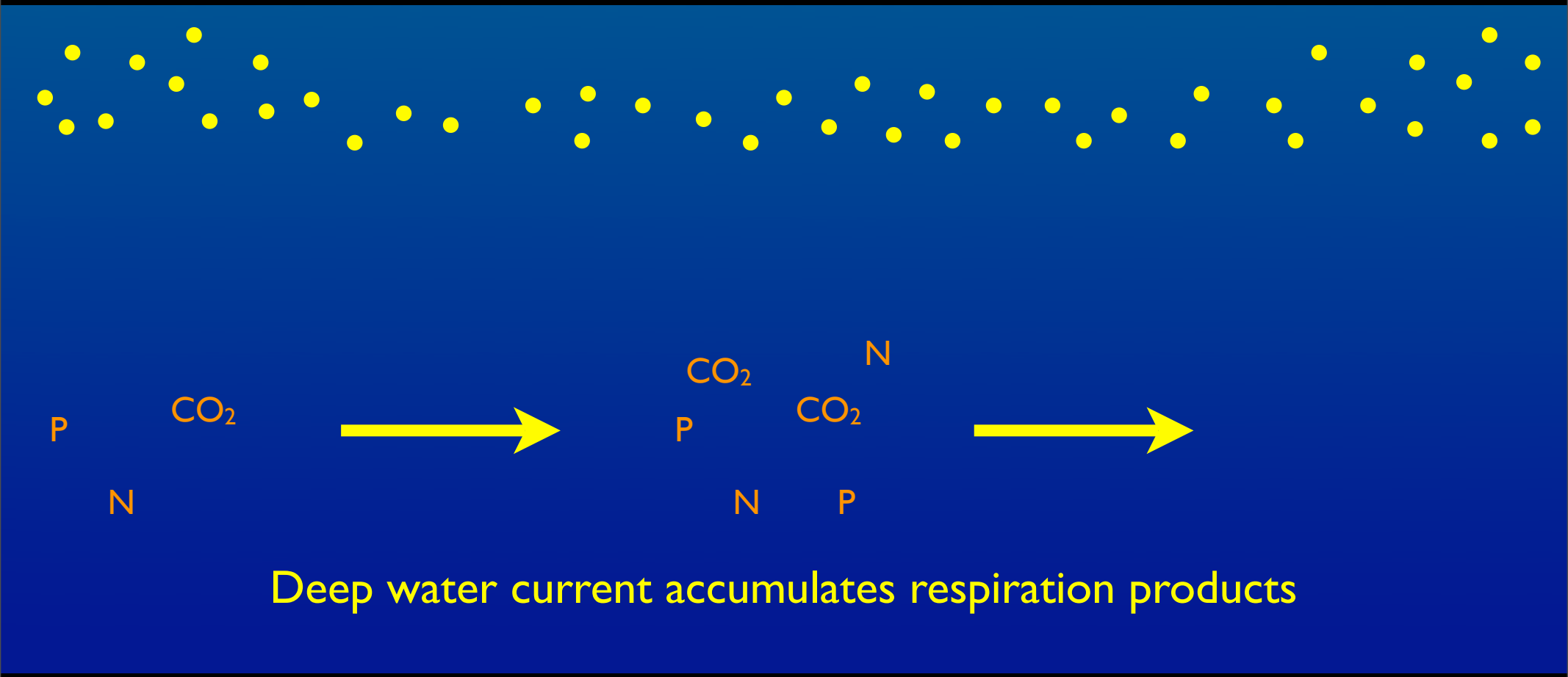
Horizontal Variations



Deep water current accumulates respiration products

Atlantic Indian Pacific

Horizontal Variations



Deep water current accumulates respiration products

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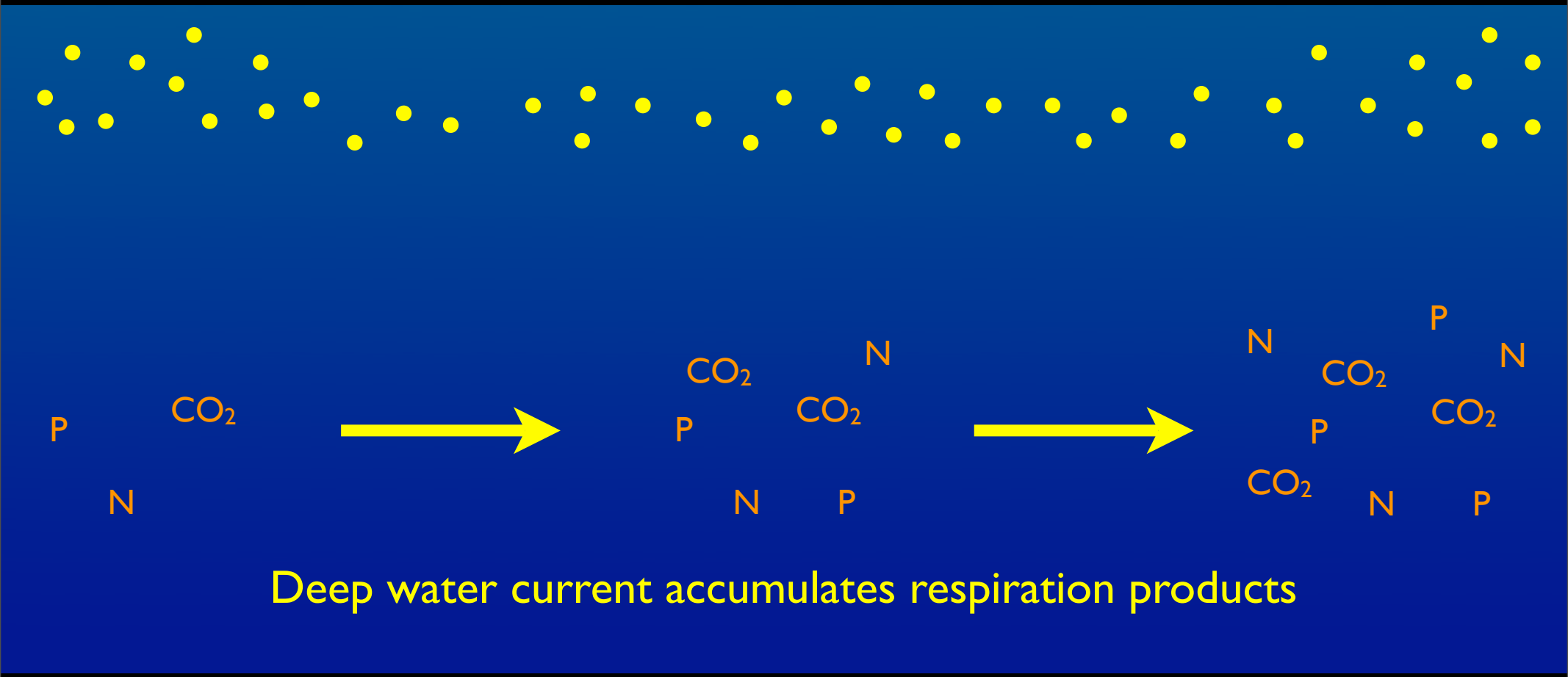
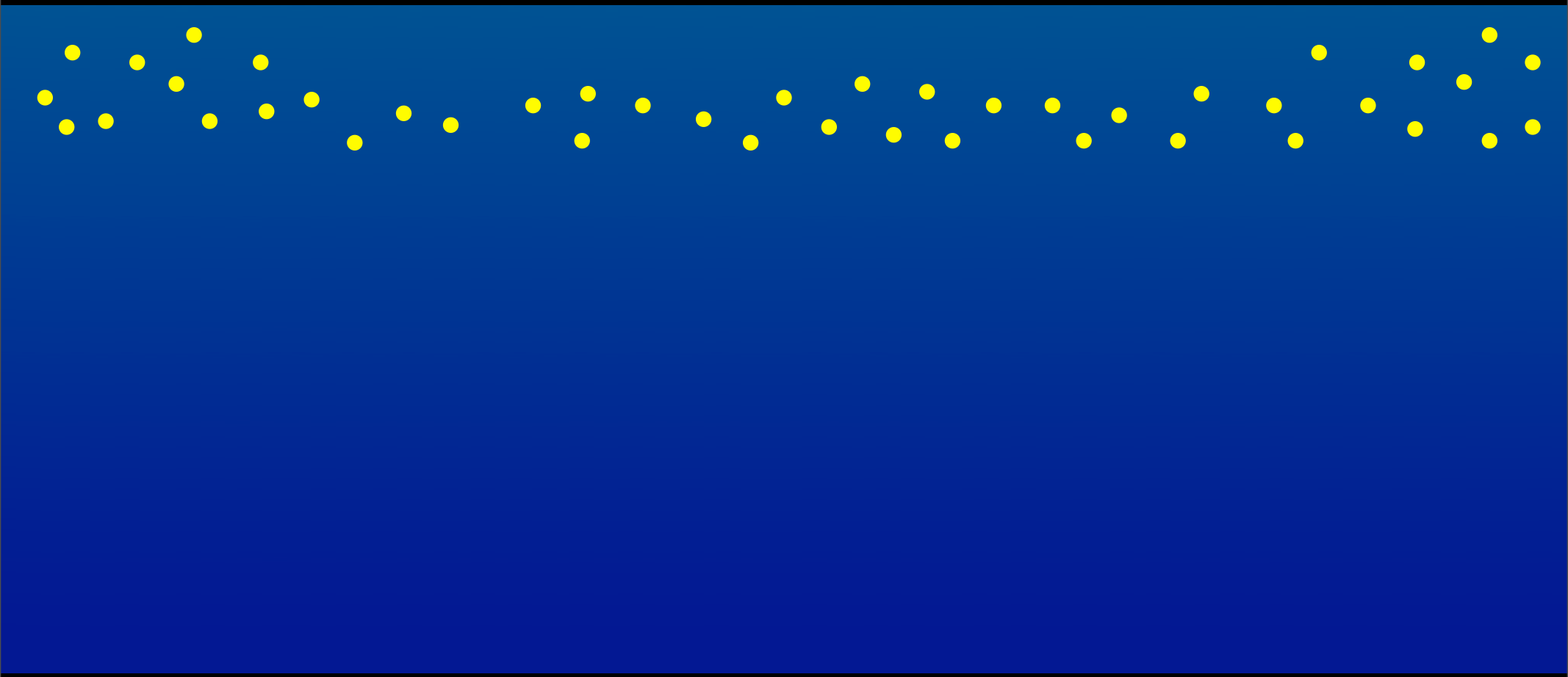
Horizontal Variations



Deep water current accumulates respiration products

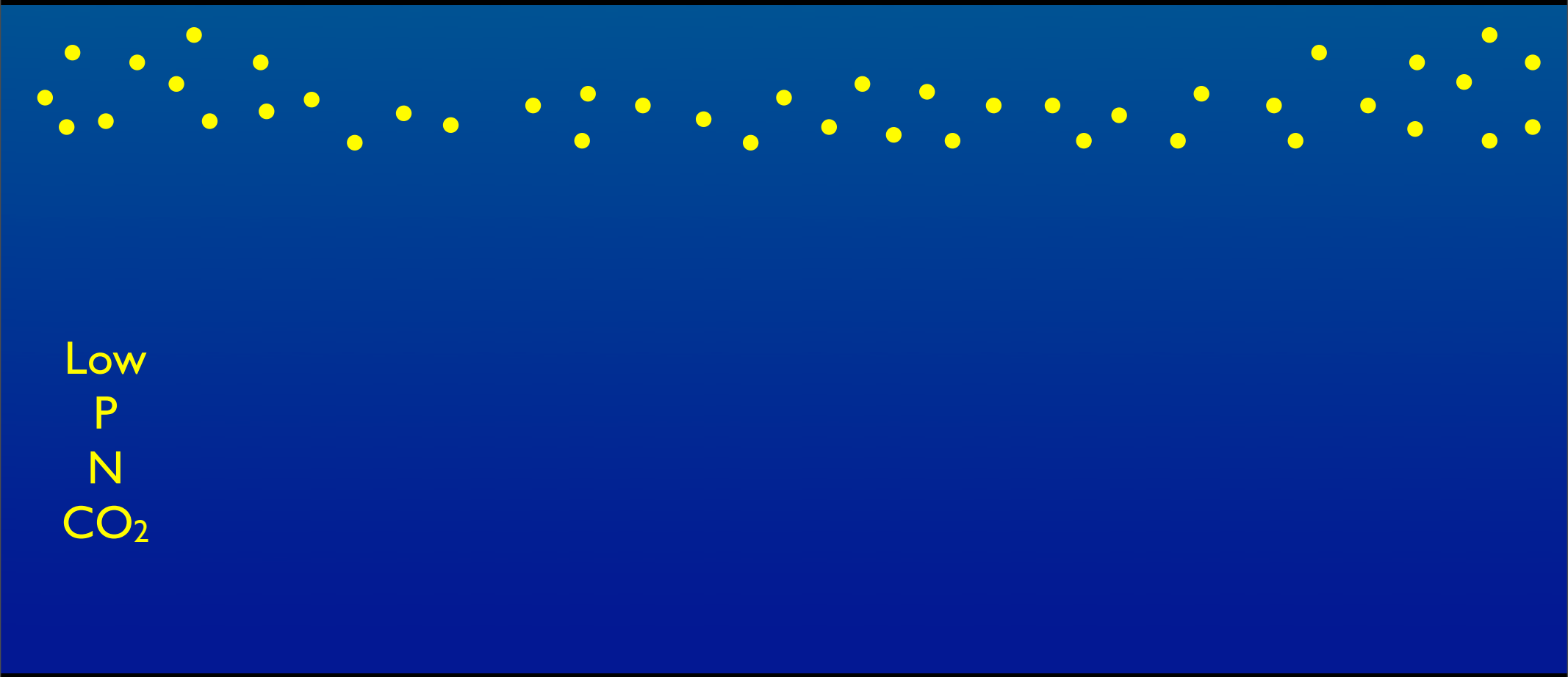
Atlantic Indian Pacific

Horizontal Variations



Atlantic Indian Pacific

Horizontal Variations



Atlantic Indian Pacific

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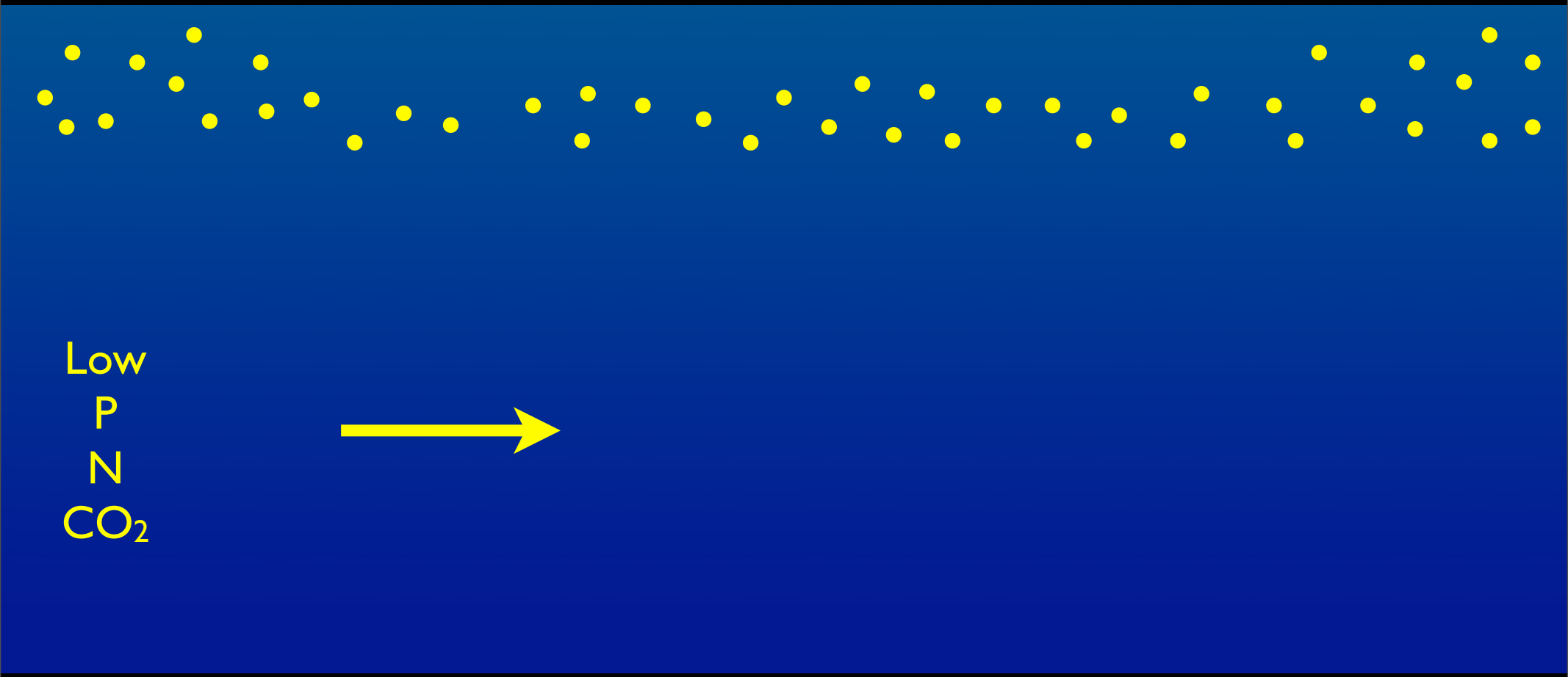
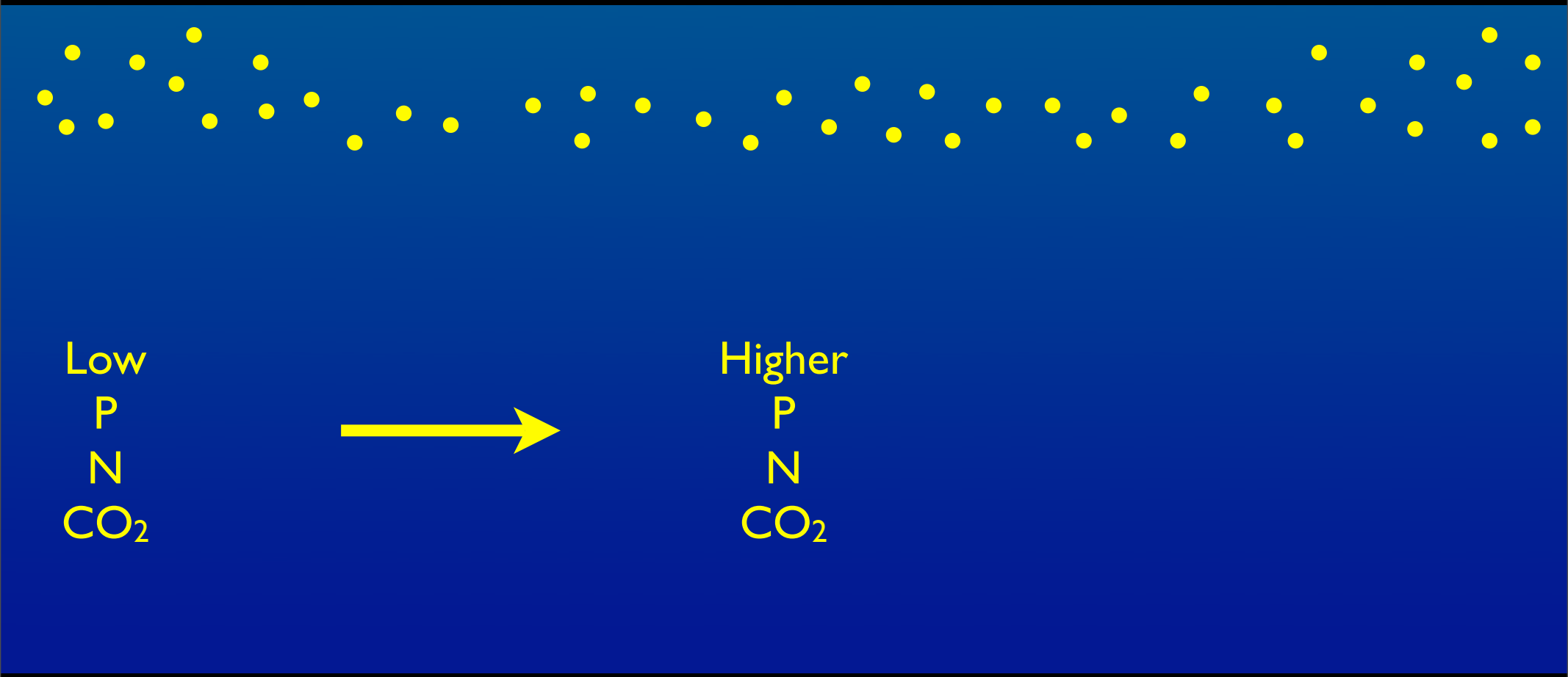


Atlantic Indian Pacific

Horizontal Variations



Atlantic Indian Pacific

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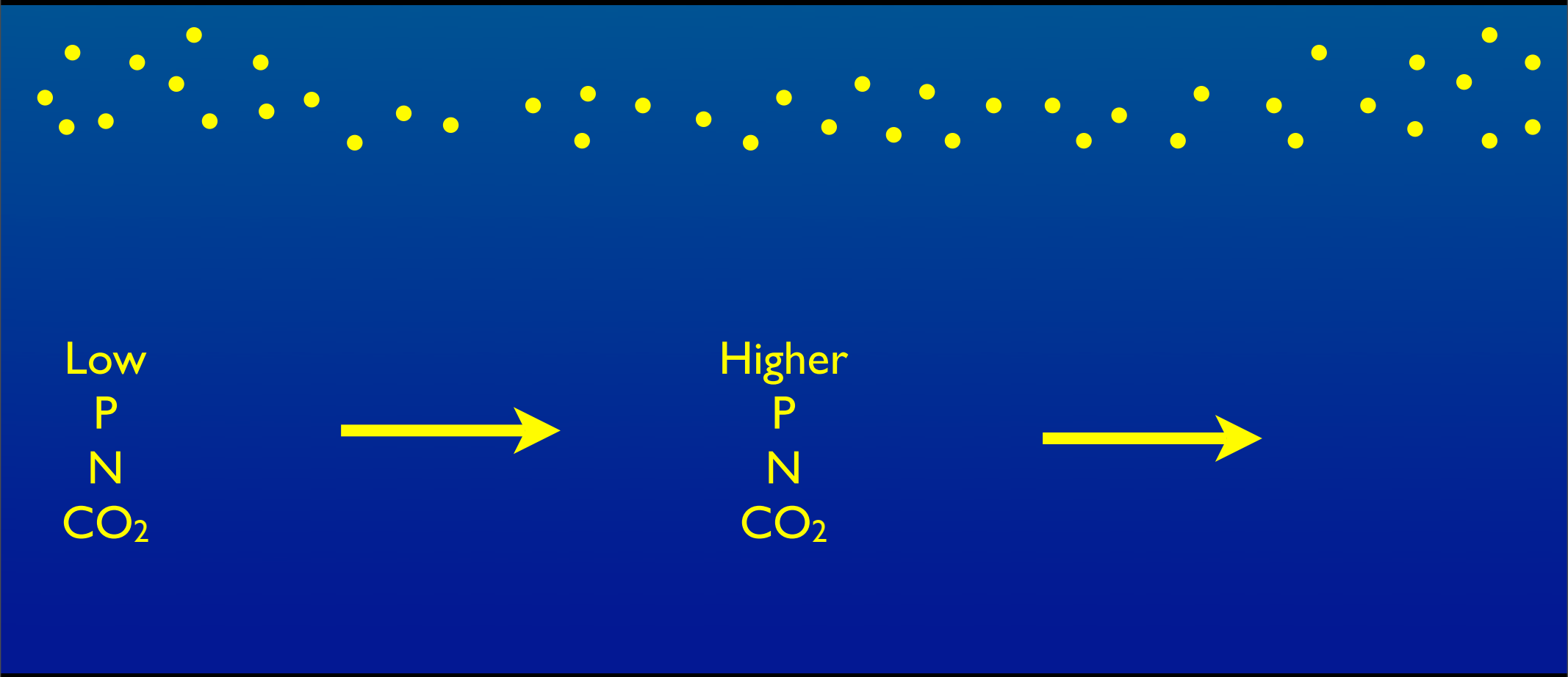
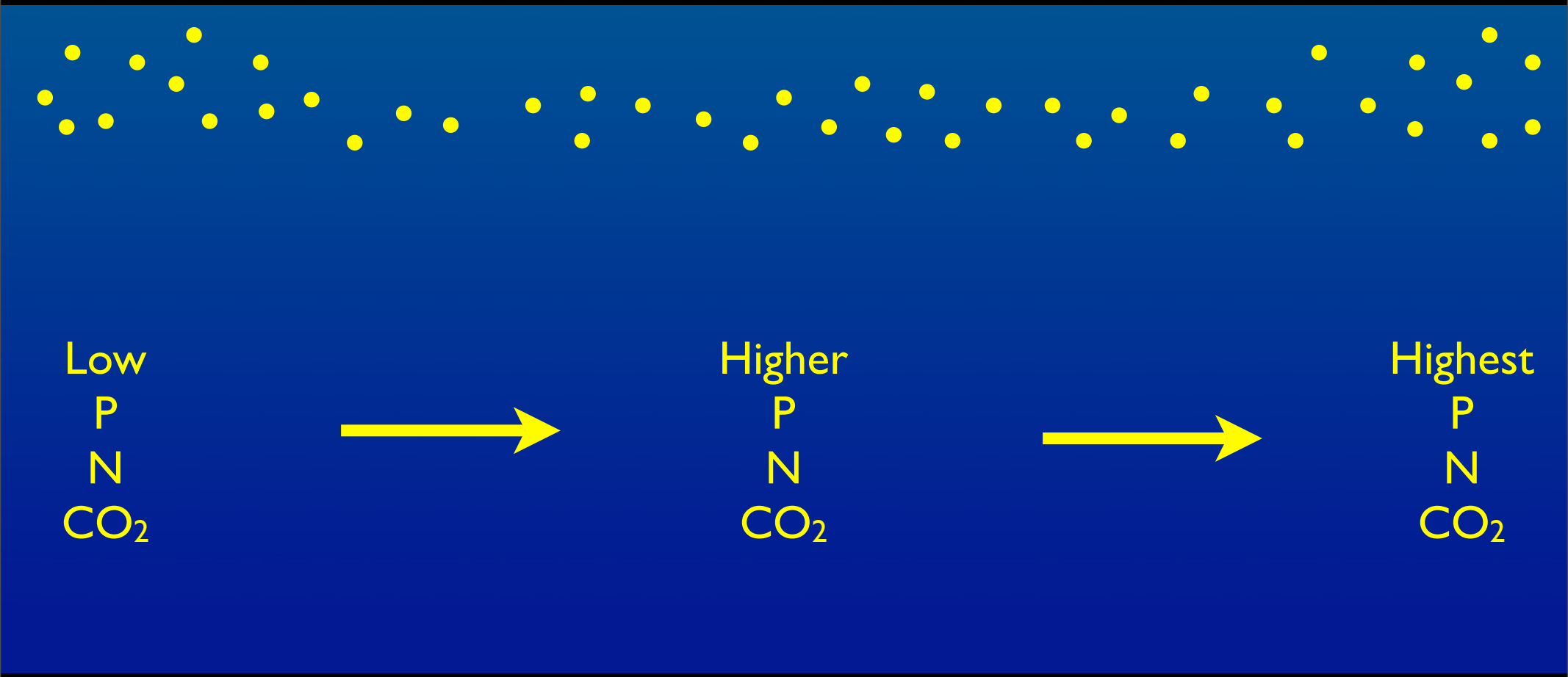
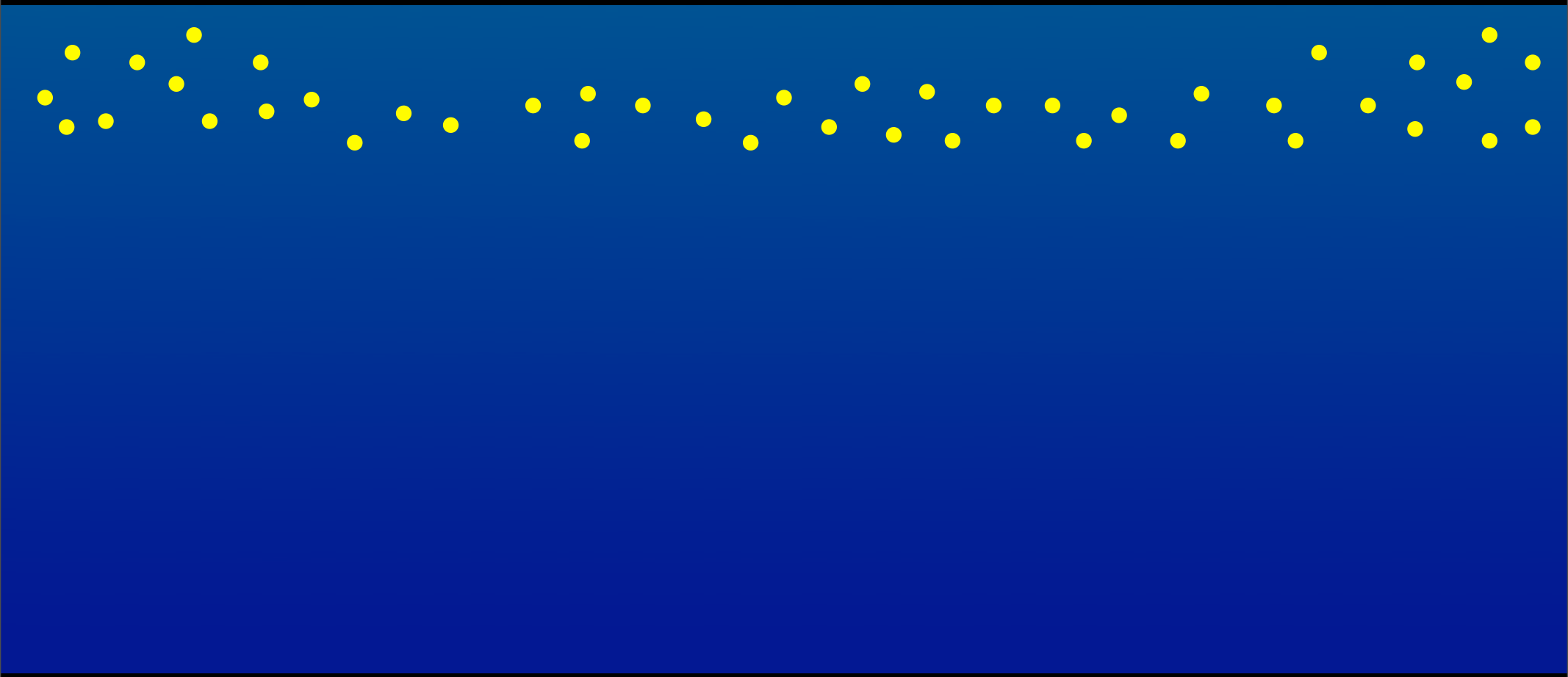


Atlantic Indian Pacific

Horizontal Variations

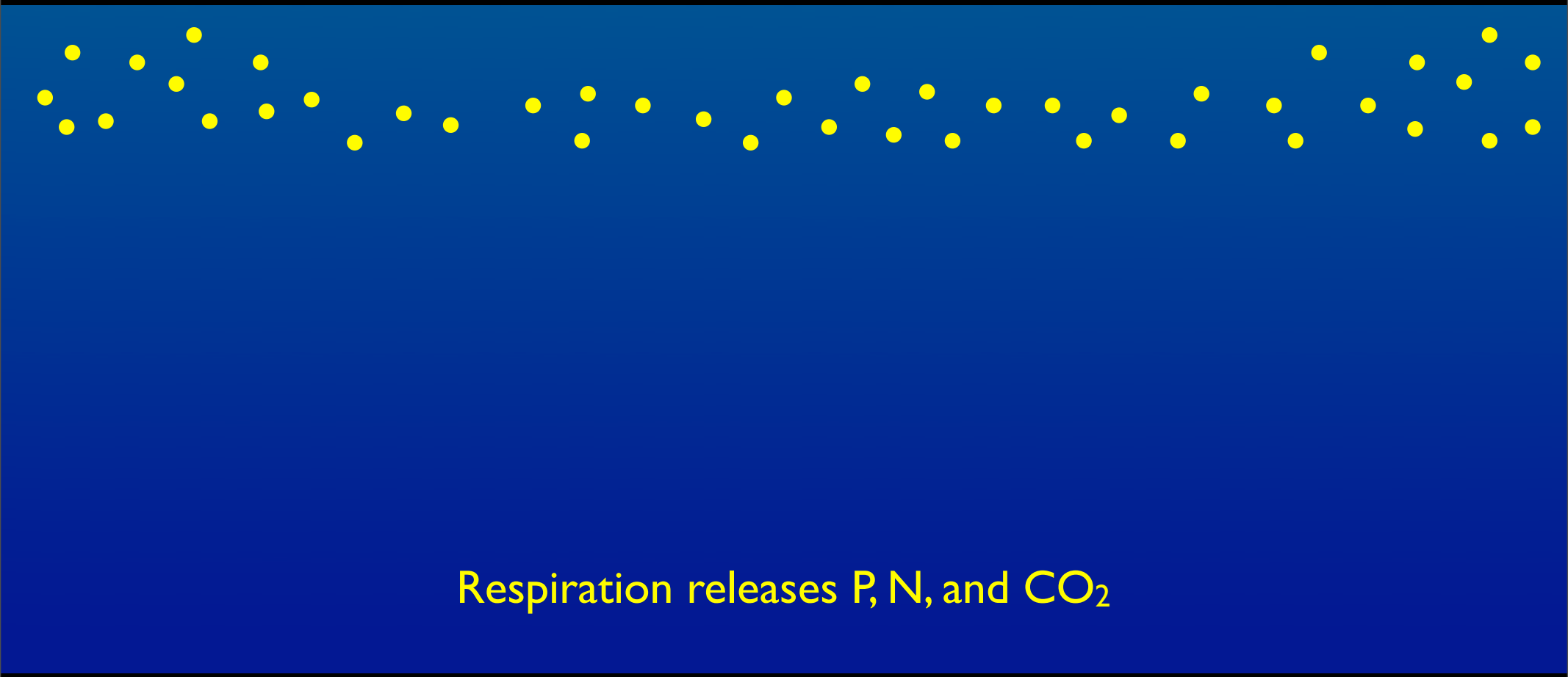


Horizontal Variations



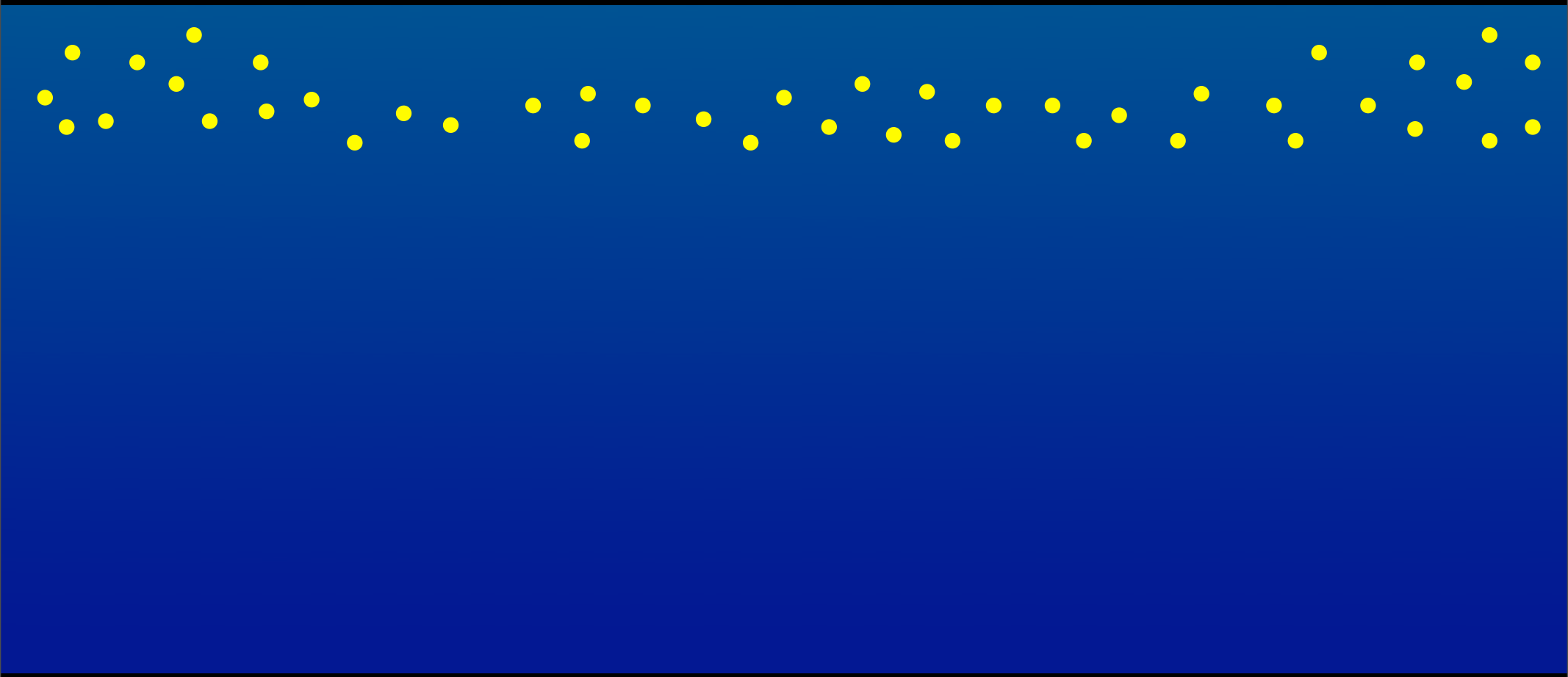
Atlantic Indian Pacific

Horizontal Variations



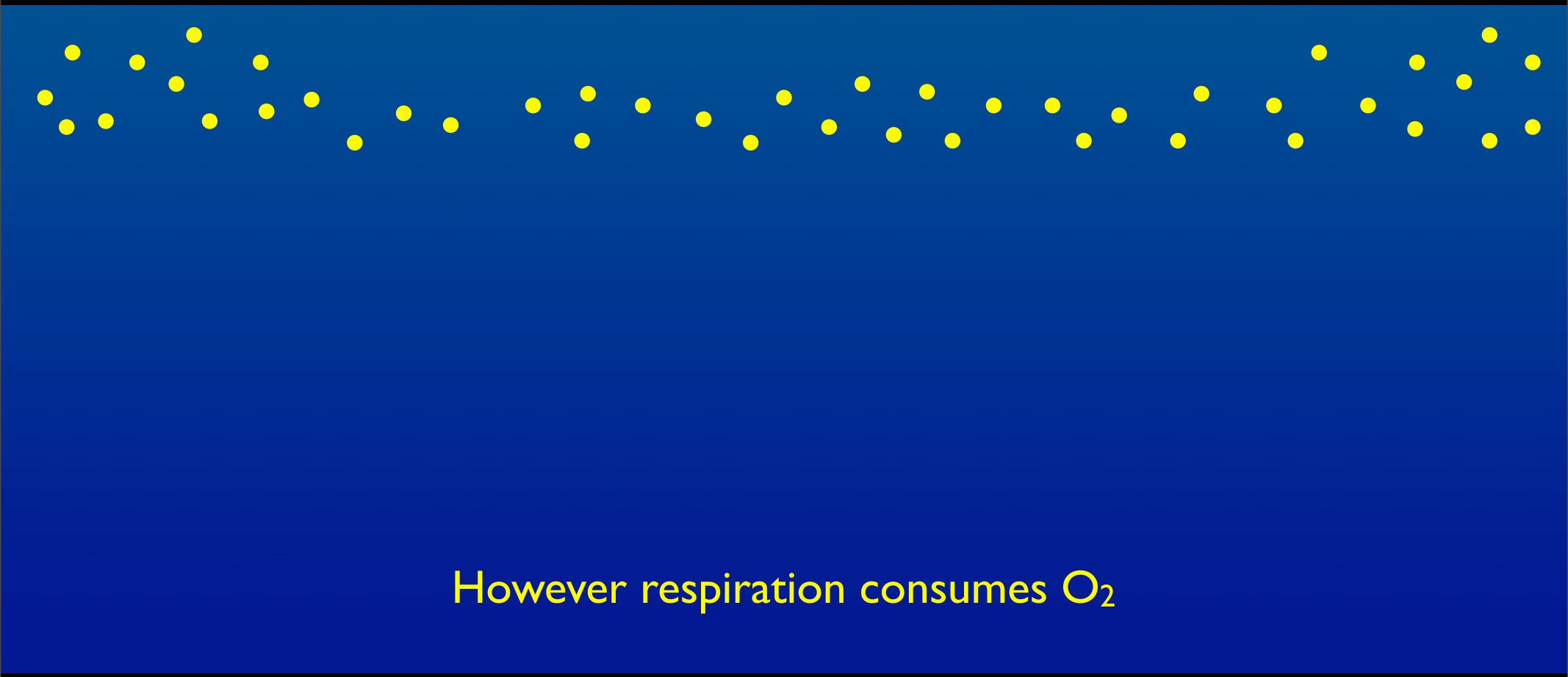
Atlantic Indian Pacific

Horizontal Variations



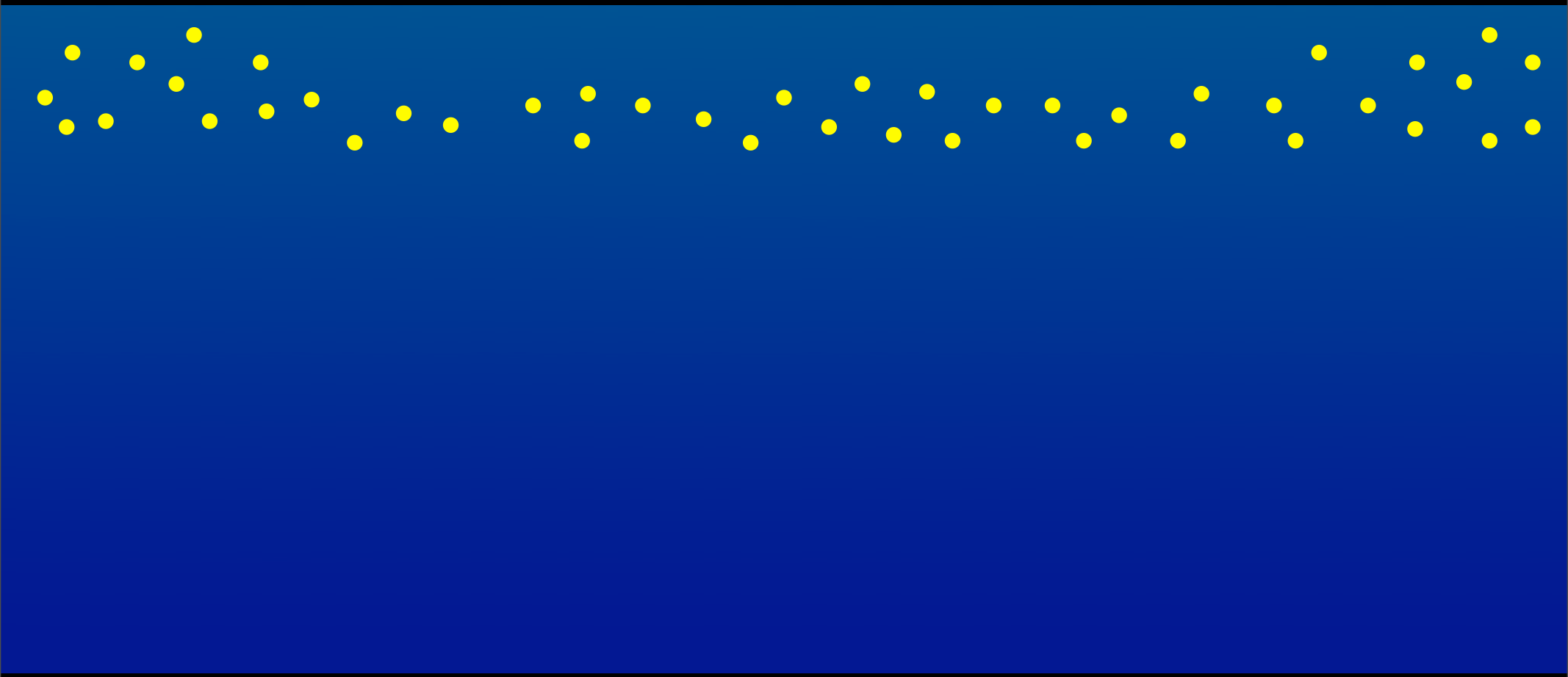
Atlantic Indian Pacific

Horizontal Variations



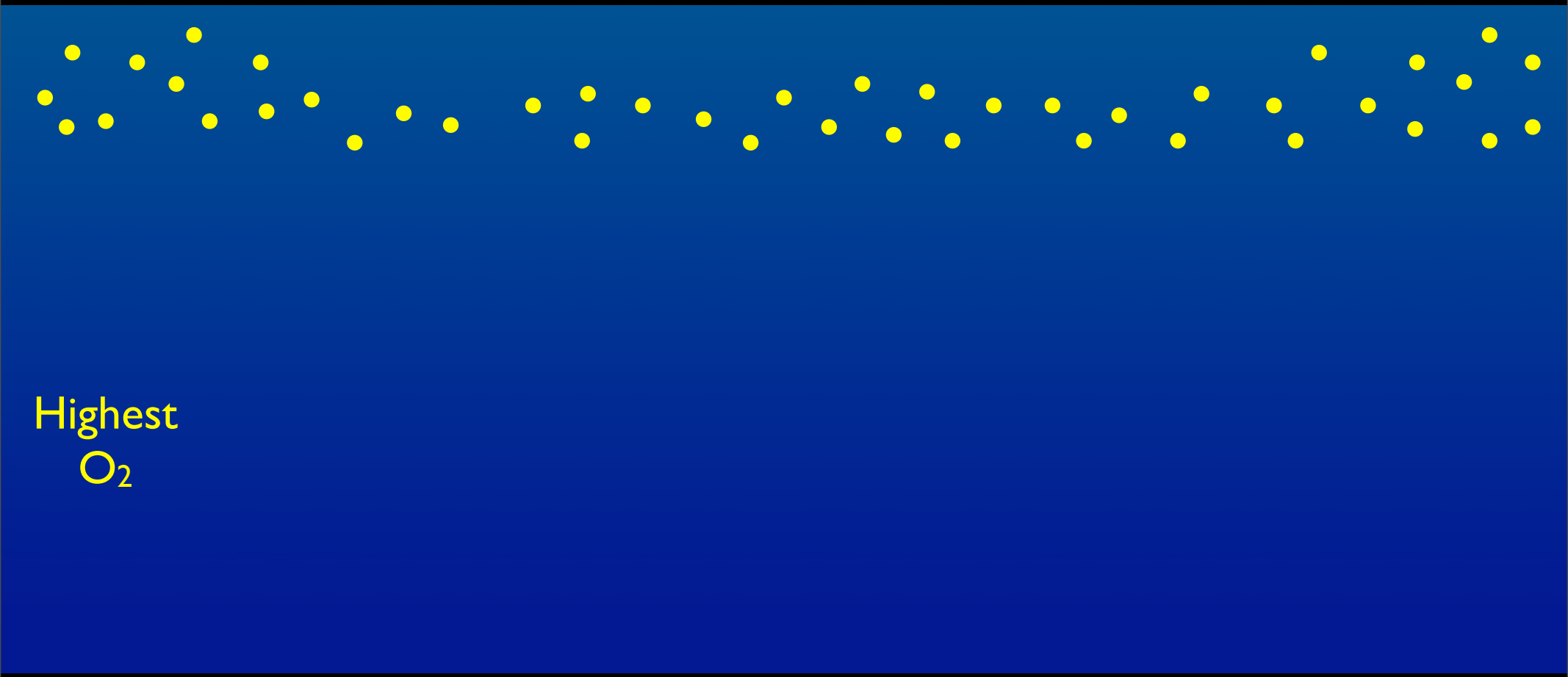
Atlantic Indian Pacific

Horizontal Variations



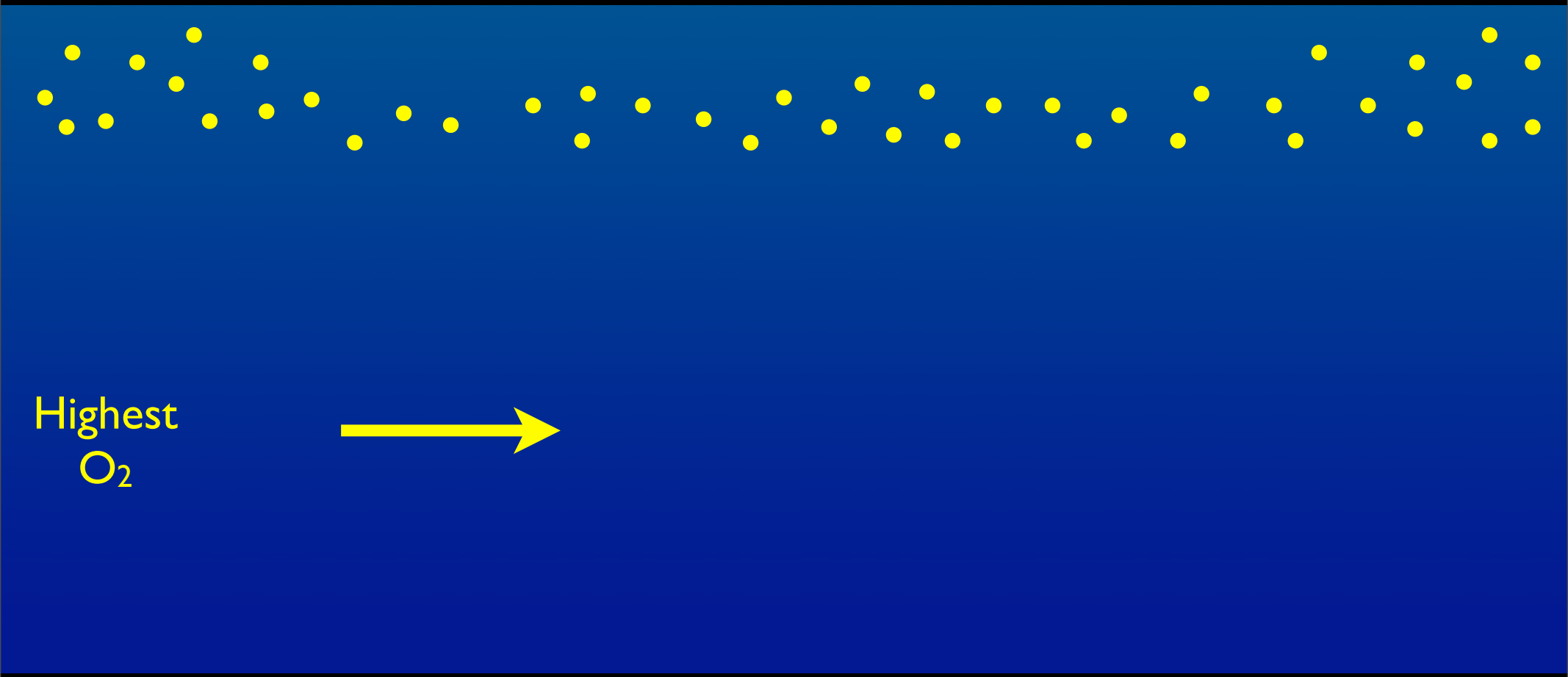
Atlantic Indian Pacific

Horizontal Variations



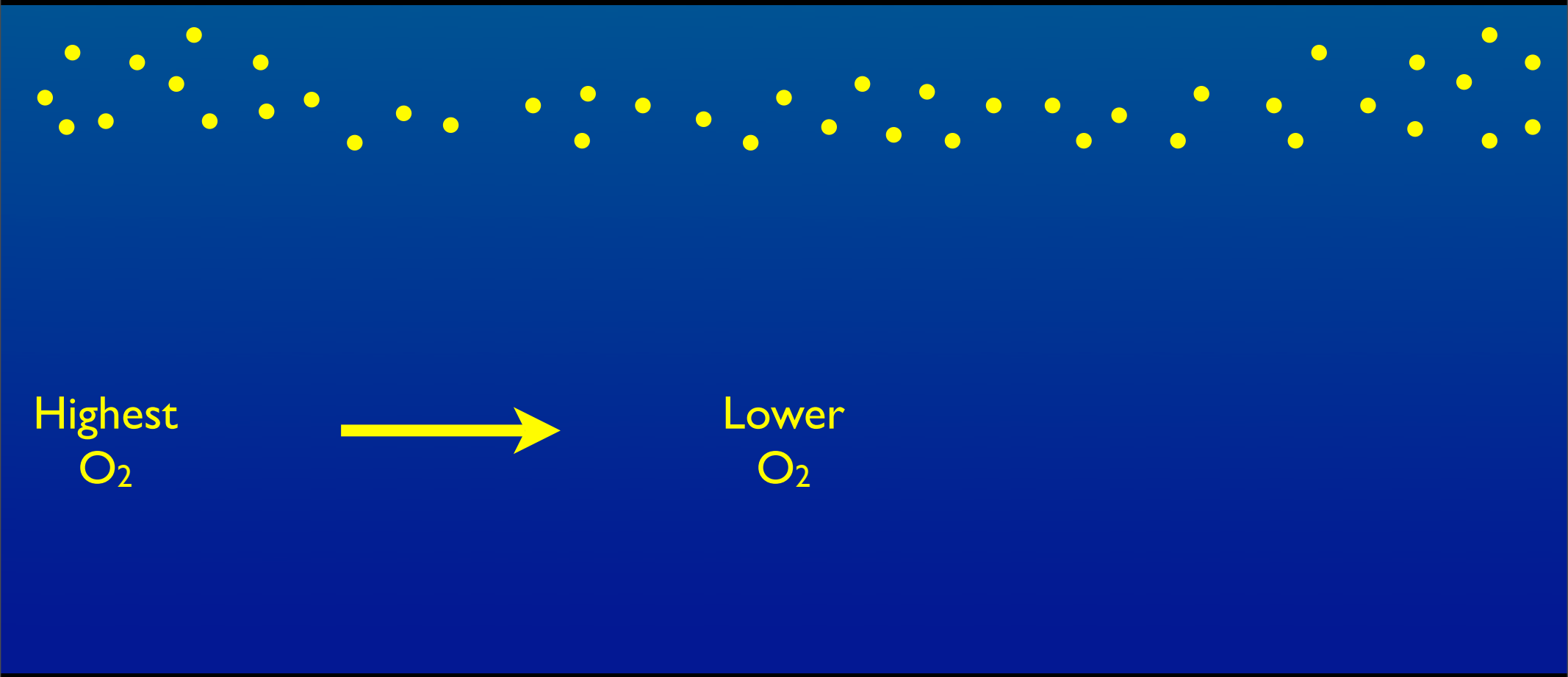
Atlantic Indian Pacific

Horizontal Variations



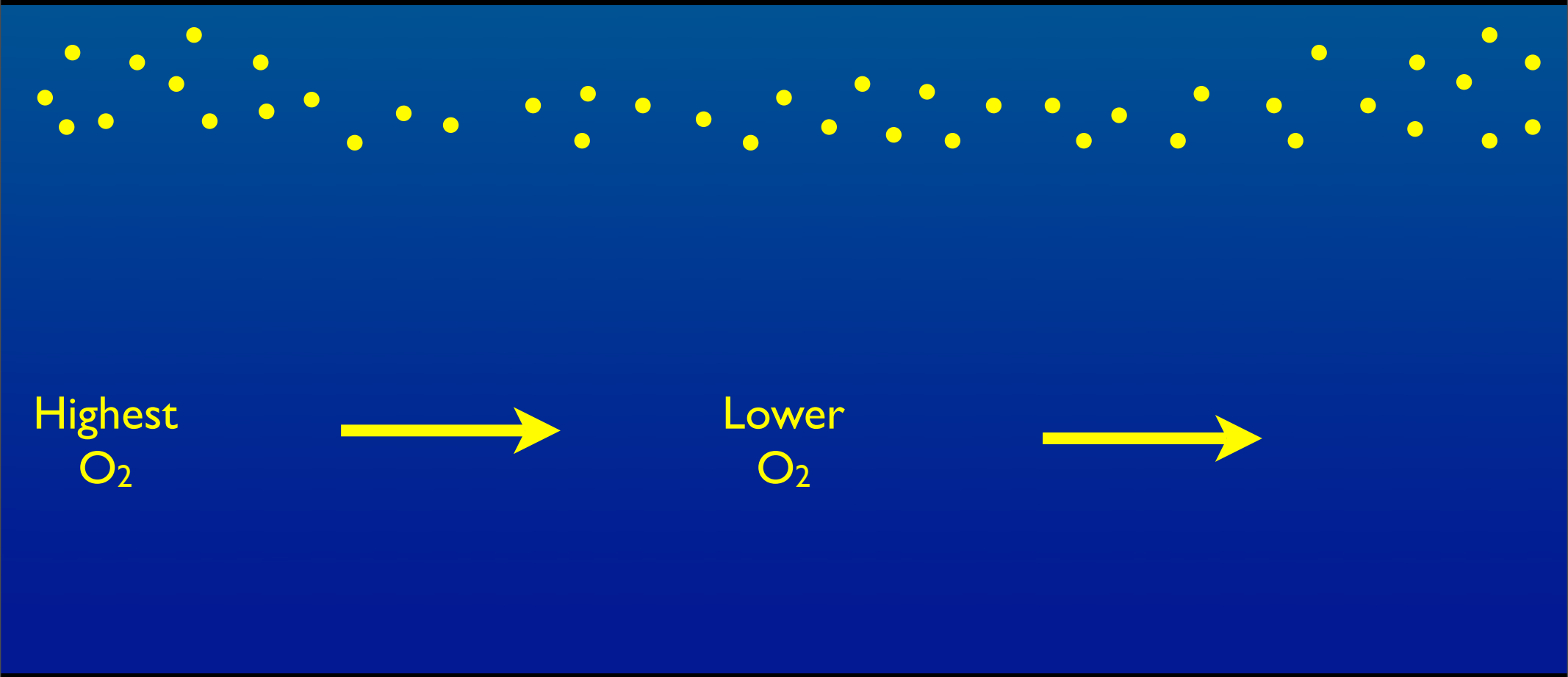
Atlantic Indian Pacific

Horizontal Variations



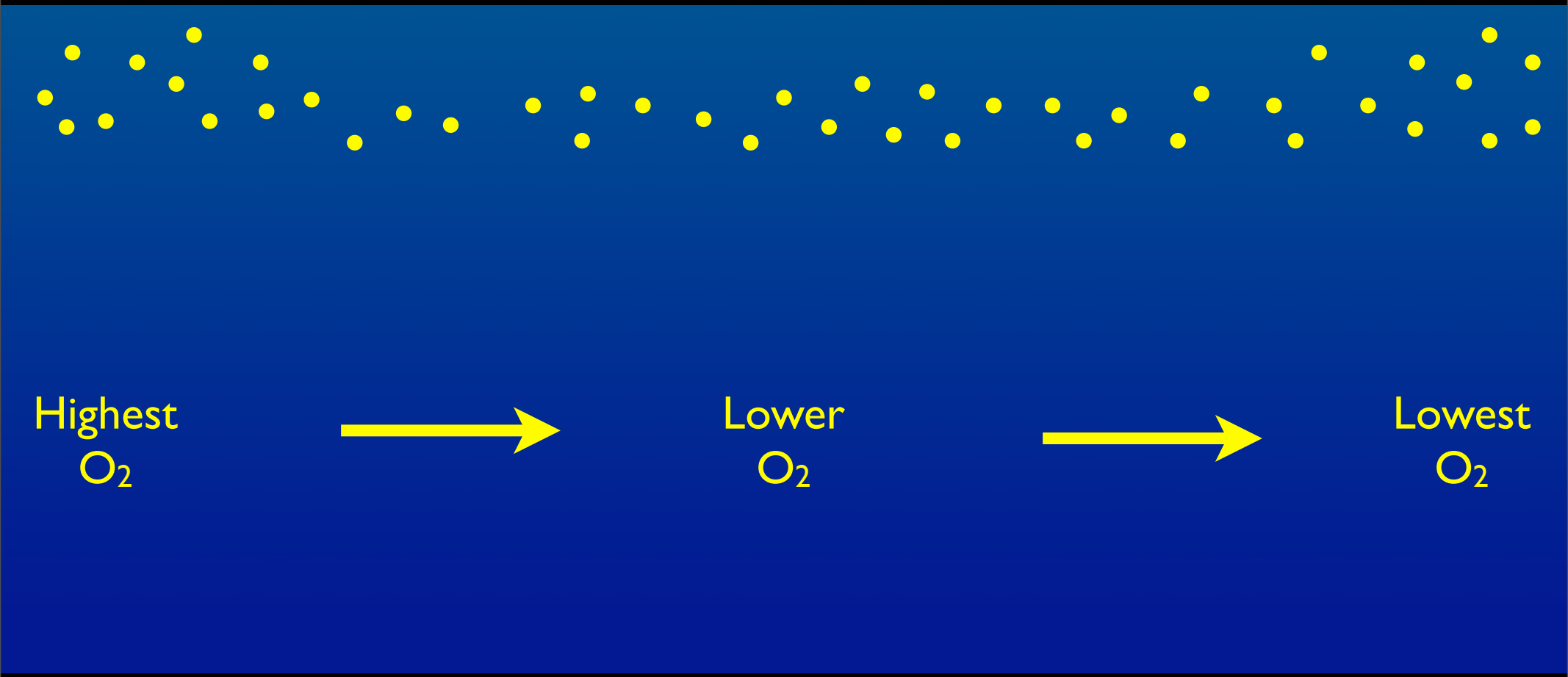
Atlantic Indian Pacific

Horizontal Variations



Atlantic Indian Pacific

Horizontal Variations



Oxygen Variation

Oxygen Variation

- Primary horizontal pattern of O_2 variation is the inverse of P, N, and CO_2

Oxygen Variation

- Primary horizontal pattern of O_2 variation is the inverse of P, N, and CO_2
- O_2 has
  - Highest concentrations in the deep Atlantic
  - Lower in the deep Indian
  - Lowest in the deep Pacific

Air-Sea Interaction

Next

Air-Sea Interaction