Aquatic Crisis Resulting in Death

a presentation for the

Tucker Redfern Pediatric Trauma Symposium

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Why we Breathe and What Happens When We Don’t

AQUATIC CRISIS

Why we breathe

- Oxygen level in blood is weakly related to the breathing reflex. This relationship is inversely proportional.

$$\downarrow O_2 = \uparrow \textbf{B}\text{reathing } \textbf{R}\text{eflex}$$

(HYPOXIA)

- Carbon dioxide level in blood is strongly related to breathing reflex. This relationship is directly proportional.

$$\uparrow CO_2 = \uparrow \textbf{Breathing Reflex}$$

(HYPERCAPNIA)

Why We Don't Breathe

- We cannot physically draw a breath
  - Blockage such as smothering or choking
  - Constriction such as positional asphyxia or crushing
  - Paralysis of muscularly supported breathing mechanism by disruption of nerve impulse
- We don't have the desire to draw a breath
  - When our body may not signal for us to draw a breath
  - A greatly reduced CO_2 level (hypocapnia) convinces our brain we don't need to breath

$\downarrow CO_2$ = $\downarrow$ Breathing Reflex

- We can breath but the environment doesn't support life
  - Chemical asphyxia is when any substance that does not contain a sufficient level of oxygen to support life makes up the breathing medium
  - Carbon monoxide – greater affinity for heme molecule
  - Inert Gases – suppress asphyxial incident anxiety/panic

What Happens When We Don’t

Passive Drowning Asphyxial Cascade

- Oxygenated blood is prevented from reaching the brain
  - Suppression of Breathing Reflex
  - Inadequate Oxygen Partial Pressure for Alveolar Ventilation
- Unconsciousness results
- Death results without intervention

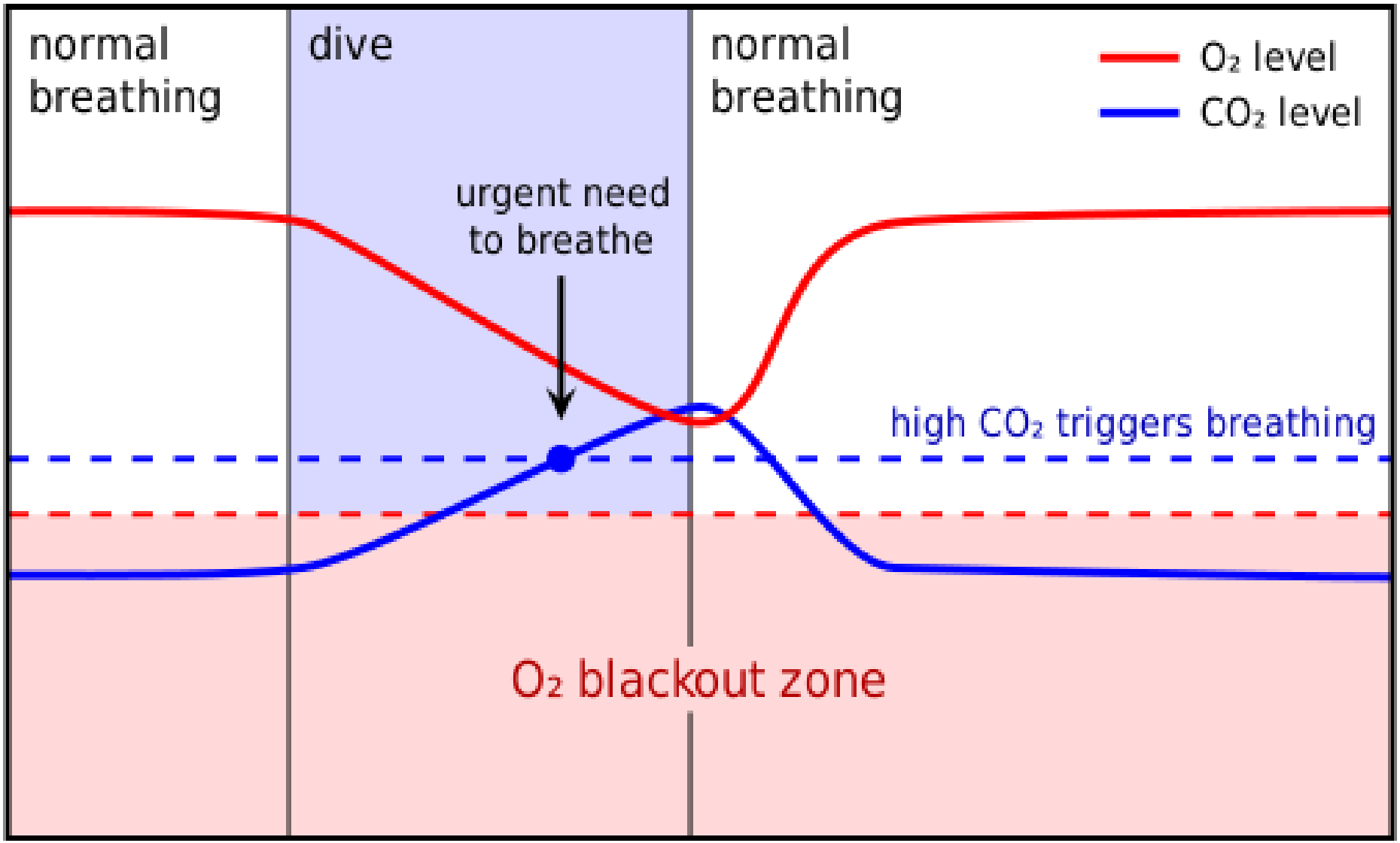
Shallow Water Blackout

- Hyperventilation
  - Abnormally low CO_2 level
  - Hypocapnia
- CO_2 level insufficient to trigger breathing reflex
- Breath Hold Distance Divers

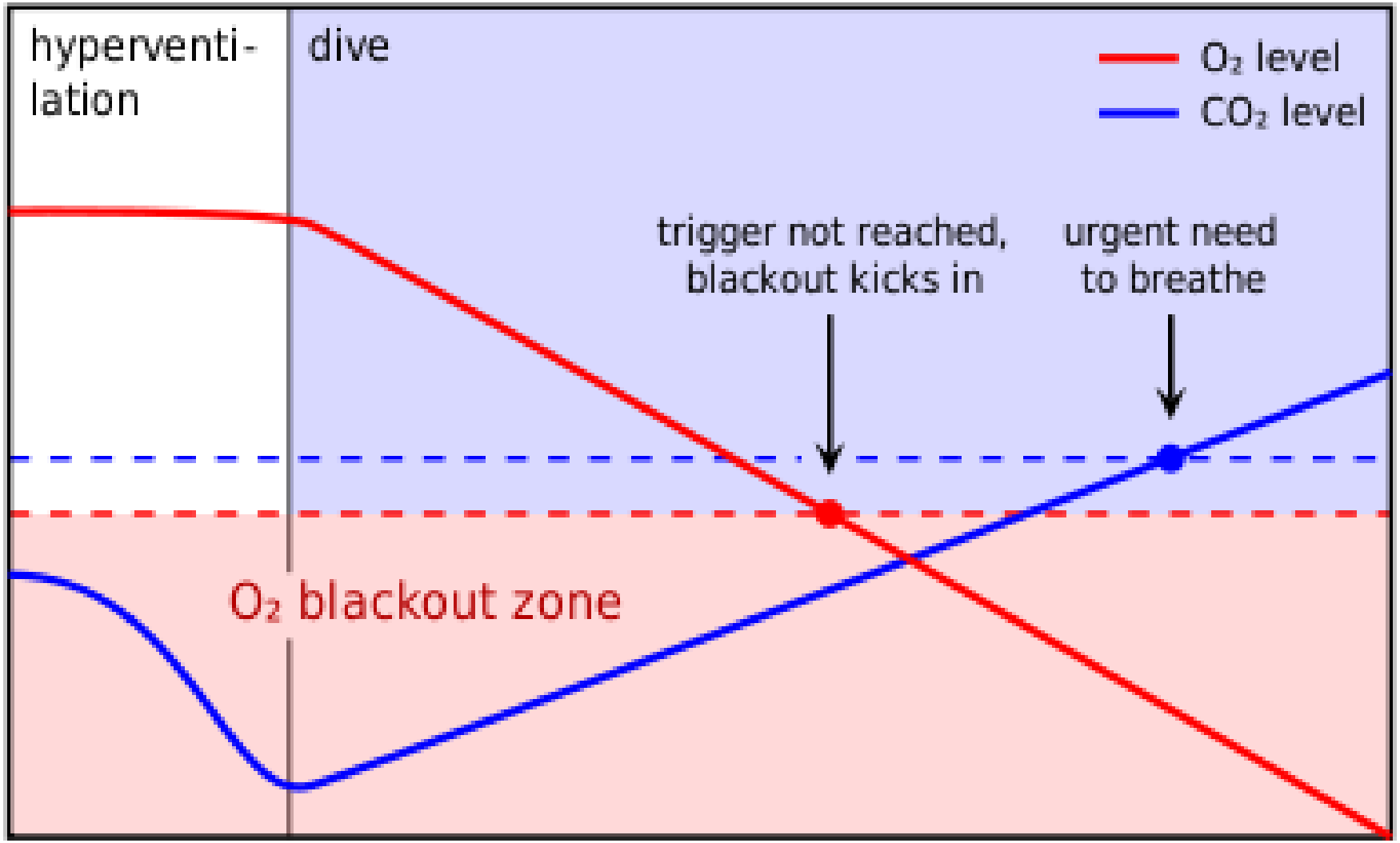
Shallow Water Blackout

- **All phases of the dive have taken place in shallow water**
- **Depressurization is not a factor**
- **Typically involves**
  - **youth, untrained diver or diver in training**
  - **dynamic hyperventilation - apnea**
  - **distance swimmers**
  - **swimming pool**
- **Primary Mechanism**
  - **Hyperventilation leading to Hypocapnia**

Normal dive


normal breathing
dive
normal breathing
O_2 level
CO_2 level
urgent need to breathe
high CO_2 triggers breathing
O_2 blackout zone

Dive with hypocapnia



Deep Water Blackout

- Hypoxia on ascent from a depth
- Partial pressure of oxygen at depth is sufficient for consciousness
- As they free ascend, oxygen level drops below consciousness threshold
- Usually occurs close to surface
- Free diver depth competitions

Deep Water Blackout

- **Breath-hold dive**
- **Deep dive (10+ meters)**
- **On ascent**
- **Manifest near surface**
- **Typically involves**
  - **Trained Free Divers**
  - **Controlled hyperventilation**
  - **Dynamic apnea**
  - **Usually salt water environment**
- **Primary Mechanism**
  - **rapid drop in the partial pressure of oxygen in the lungs on ascent**
  - hypocapnia may be involved even if ascent is the actual precipitator.

Freediving it's the Law

- Boyle's Law (↑ Pressure ↓ Volume)
  - As the diver goes deeper the volume of the air in their lungs decreases.
  - As the volume of the gas decreases, the concentration of those gases is greater.

- Dalton's Law (the total pressure of a mixture of gases is equal to the sum of its partial pressures of each of the different gases)

Partial Pressure as Depth Increases

Depth of Free Dive	Partial Pressure of Oxygen	Partial pressure of Nitrogen
0 meters	0.21	0.79
10 meters	0.42	1.48
20 meters	0.63	2.37
30 meters	0.84	3.16
40 meters	1.05	3.95

- As the depth increases the partial pressure of the oxygen within the lungs.
- A partial pressure of 0.1 is required for gas exchange to take place in the alveoli
- A drop below 0.1 in the partial pressure of oxygen results in unconsciousness

Example:

Depth of Free Dive	Partial Pressure of Oxygen	Partial Pressure at depth Remaining After Exertion
0 meters	0.21	
10 meters	0.42	<0.1
20 meters	0.63	
30 meters	0.84	
40 meters	1.05	0.40

- Freediver starts with 0.21 partial pressure at the surface
- Descends to 40 meters where the partial pressure (if no oxygen was expended during dive effort)
- With dive effort partial pressure is now 0.40, still greater than surface partial pressure.
- On ascent, partial pressure continues to decrease until at 10 meters it is below 0.1 and the diver goes unconscious

Submersion Syndrome (Mammalian Dive Reflex)

- Immersion of the face in cooler water, generally below 70 degrees Fahrenheit.
- Natural Energy Saver Mode
  - Decreased heart rate
  - Peripheral vasoconstriction to centralize the blood to the core
  - Shifting of the blood to the thoracic cavity provides countering pressure to the increased water pressure

Mammalian Dive Reflex

- May result in significantly longer post incident resuscitation viability
- May result in significantly decreased damage to brain and other tissues due to hypoxic episode

Active Drowning Asphyxial Cascade

- Victim finds themselves in an aquatic crisis when they can no longer keep their head above water and support breathing
- Extreme physical activity as efforts are made to self rescue
- Exhaustion results in subsiding effectiveness of efforts
- Progressive asphyxia as oxygenated blood is prevented from reaching the brain
  - Laryngeal spasm from water contact
  - Inhalation of water into airway, bronchi, alveoli
  - May include aspiration of vomitus and cough/inhale cycle
- Unconsciousness results
- Death Results without intervention

Death in Drowning

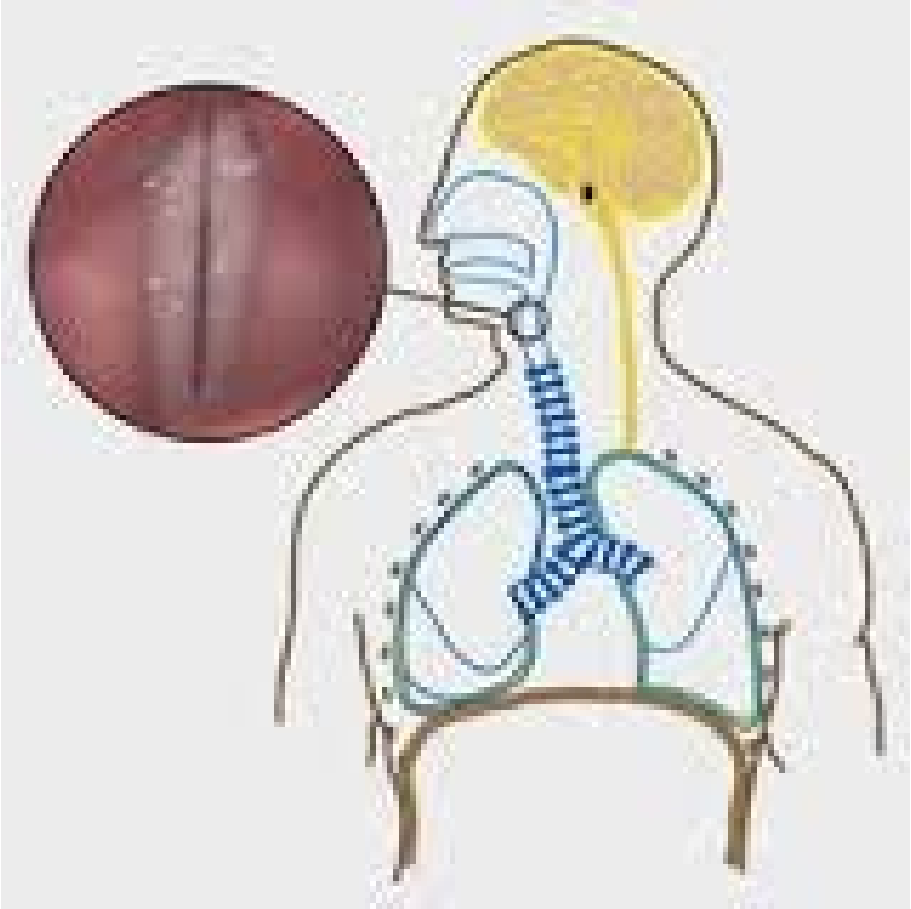
- Cause: irreversible cerebral anoxia
- Potential mechanisms leading to death
  - Cardiac arrhythmia
  - Electrolyte imbalance
  - Vagal Stimulation
  - Laryngeal spasm

Mechanism of Death

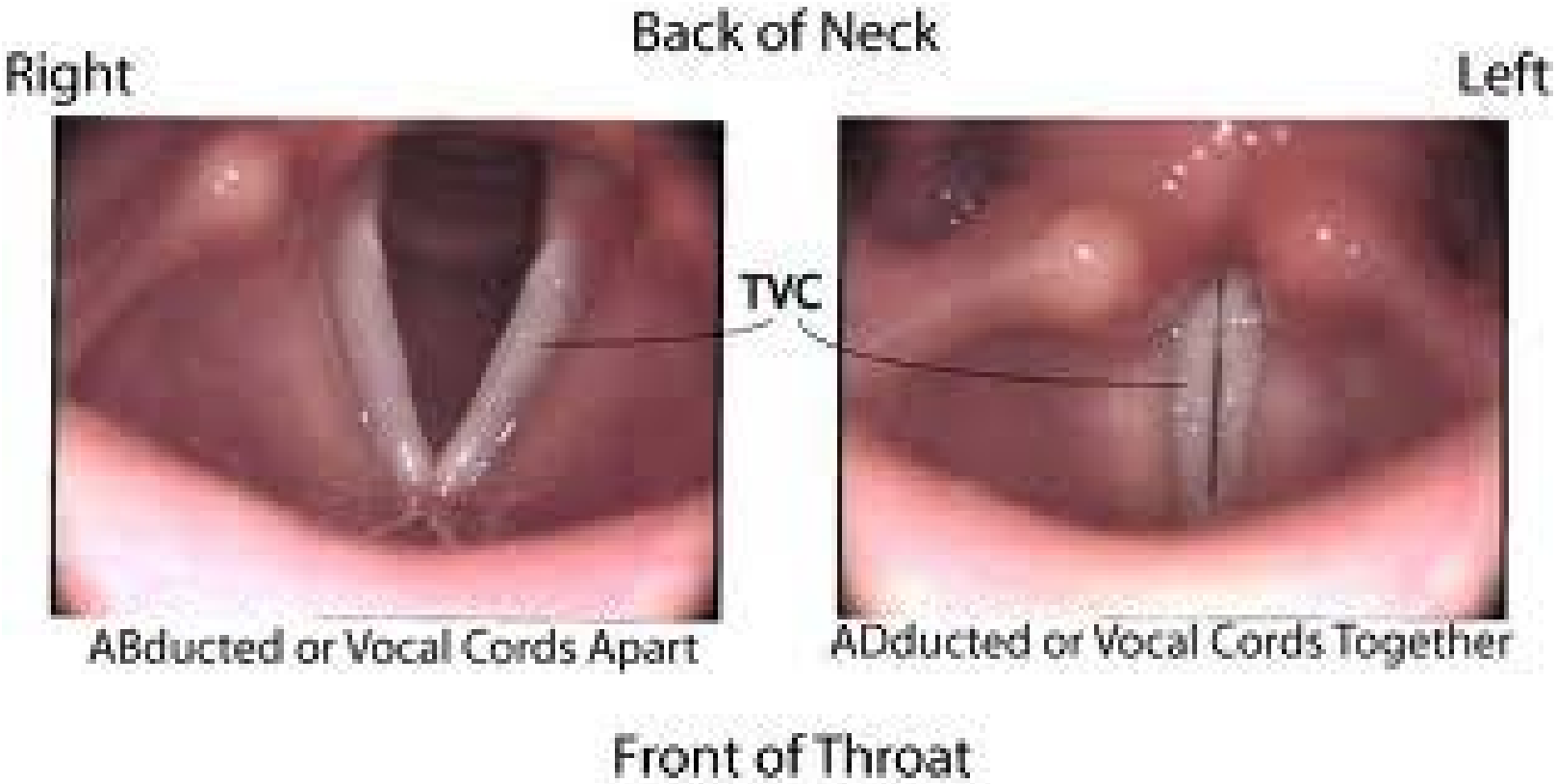
DROWNING

Dry Drowning

- Asphyxial due to laryngospasm. The vocal chords (larynx) constricts and seals the airway.
- Water does not enter the lungs but may enter the stomach. The bloated stomach may hinder CPR efforts on rescue and will adversely effect natural breathing as it restricts diaphragm movement.

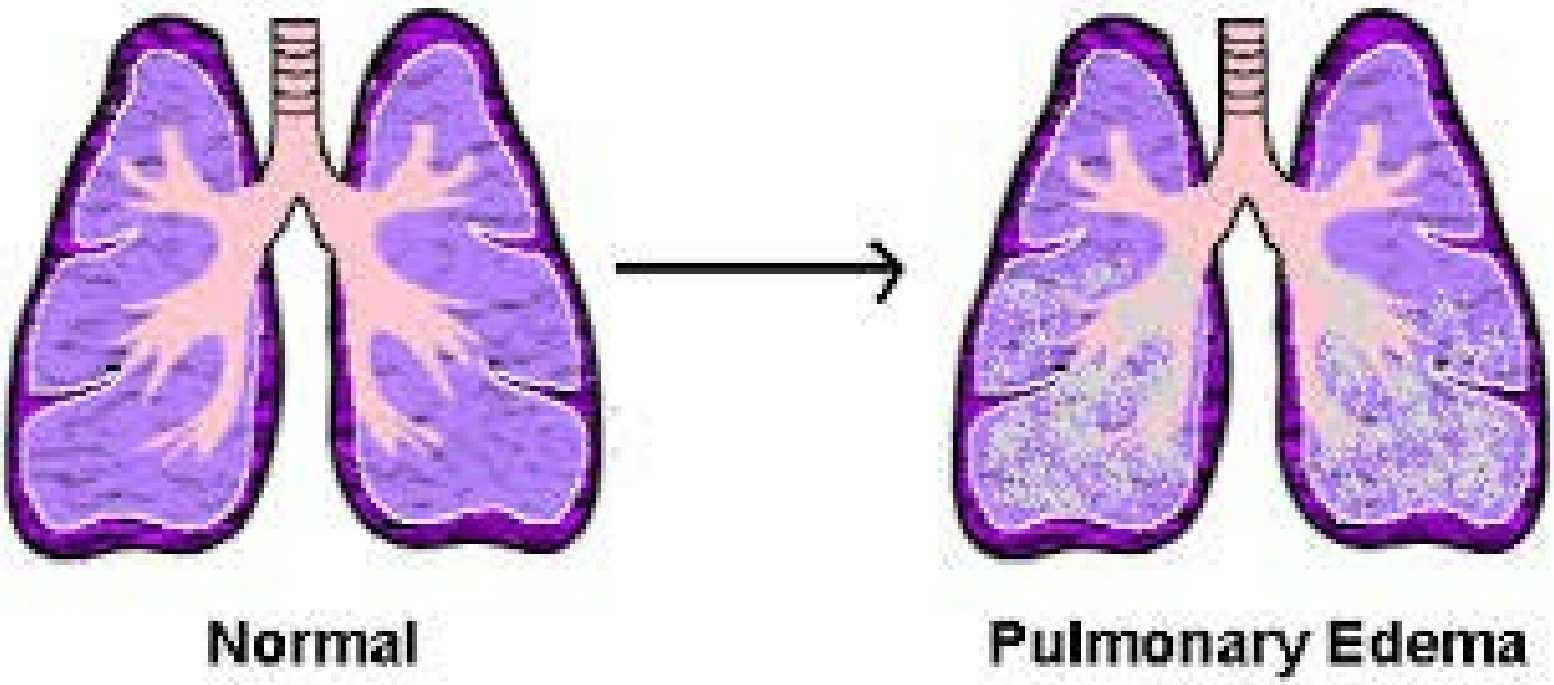


Laryngospasm



Wet Drowning

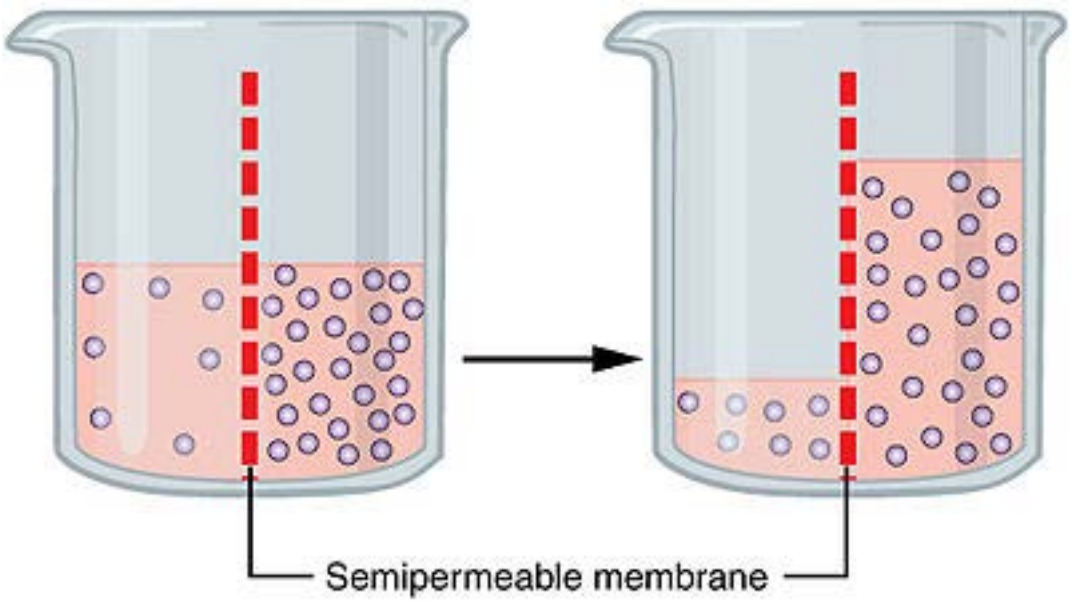
- Water enters the lungs



HOW DO SALT WATER AND FRESH WATER DROWNING DIFFER?

Understanding Osmosis

- Movement of water from an area of greater concentration to an area of lesser concentration across a semi-permeable membrane.



Fresh Water Drowning

- Freshwater in the lungs crosses into the pulmonary circulatory system in an attempt to dilute the blood until there is an equal water balance on both sides.
- The rapid dilution of the blood causes hemolysis (bursting of the red blood cells)
- Imbalance in Potassium and Sodium within the system may quickly (2 to 3 minutes) lead to ventricular fibrillation.

Salt Water Drowning

- Sea water has a greater mineral concentration than blood. It is a hypertonic solution. The water in the blood passes out of the pulmonary circulatory system in an attempt to dilute the sea water in the lungs until a balance is reached.
- The blood very quickly becomes more viscous and significant strain is placed on the heart which may lead to cardiac arrest in as quickly as 10 minutes.

Delayed or Secondary Drowning

- Near drowning incident
- Generally involves younger children
- Small amount of water in lungs
- Pulmonary edema
- Death may occur an hour, or hours later
  - Coughing
  - Wheezing
  - Change of awareness
  - Frothy sputum

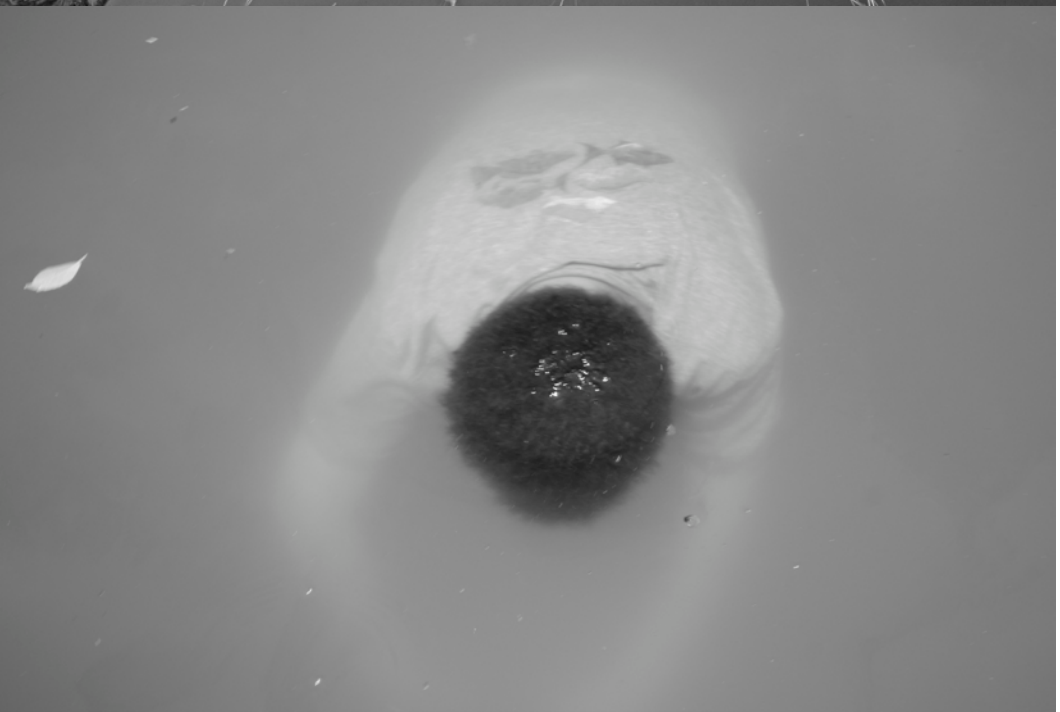
The Forensic Perspective

My World

AQUATIC RECOVERY OF EVIDENCE & HUMAN REMAINS

SURFACE SEARCH

Body floating at surface. Viewed without polarizing lens (sunglasses or camera filter). Note that the reflection from the surface of the water obscures most of the body from view.



Body floating at surface. Viewed with polarizing lens. The reflection from the surface of the water has been eliminated and the body is easier to view.

ARIAL SEARCH

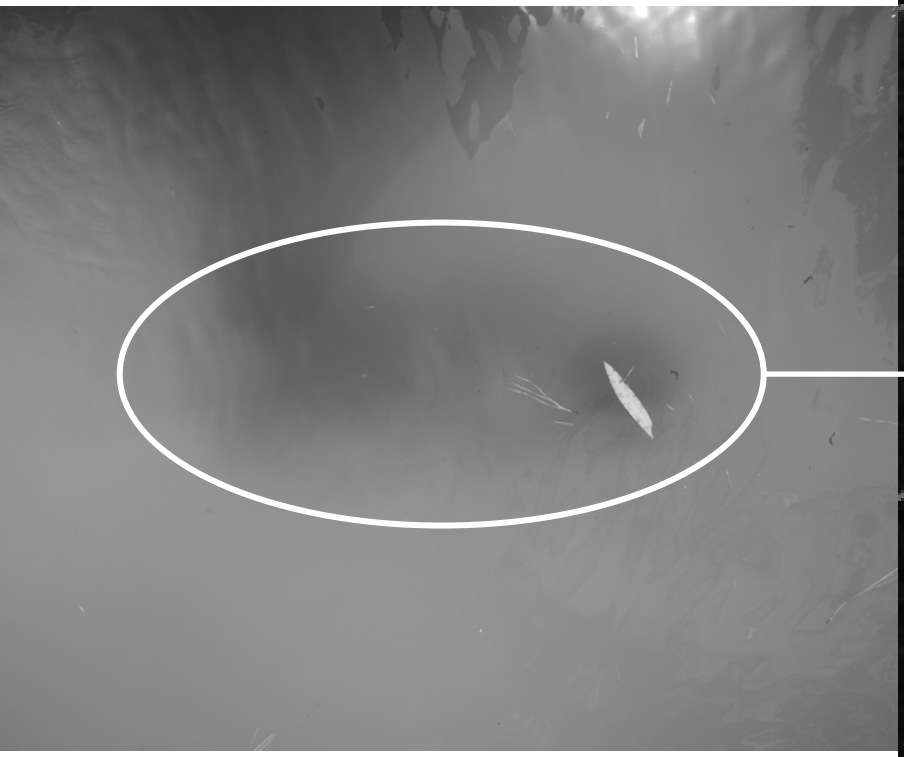

UNDERWATER SEARCH

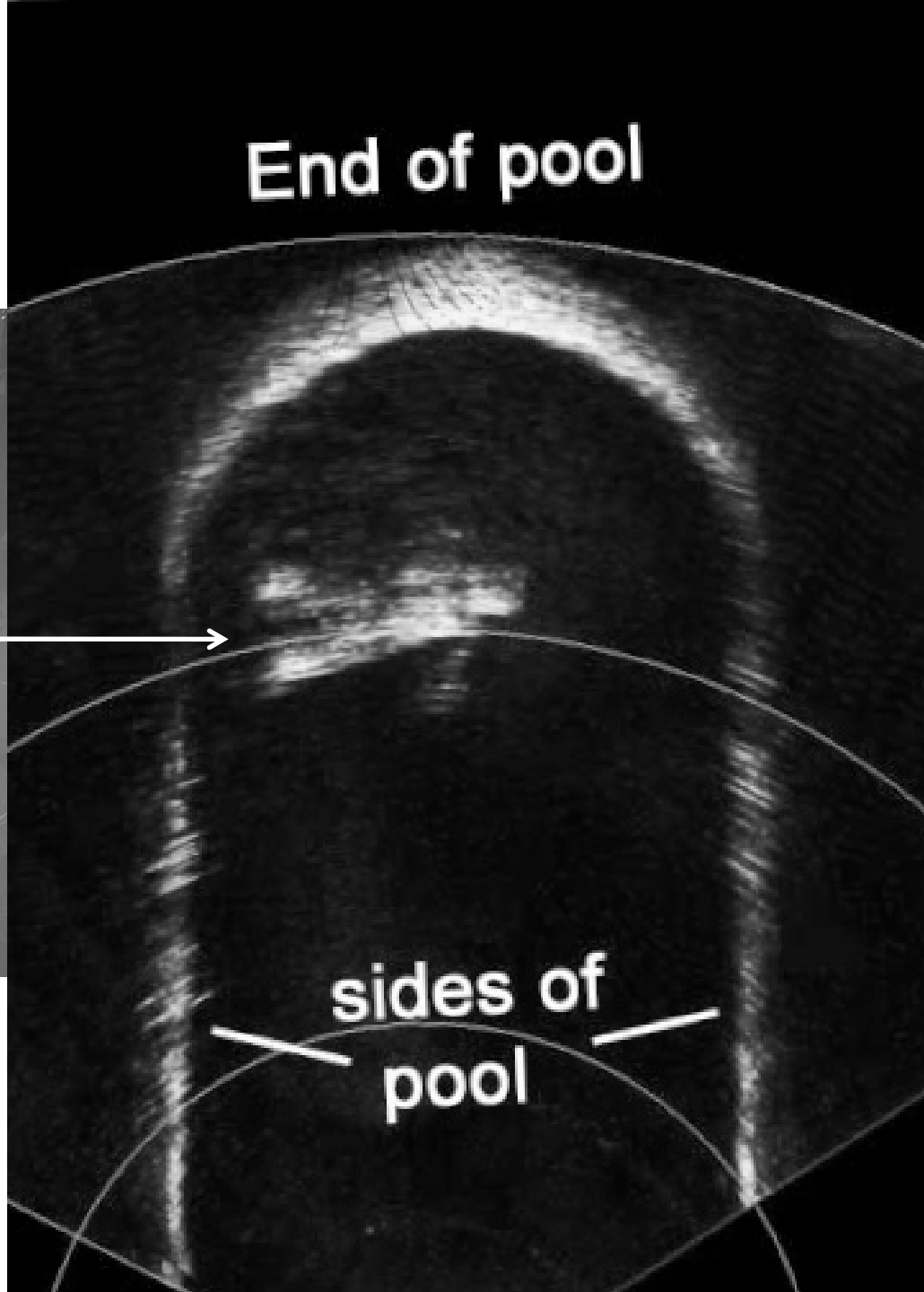
Other Methods

- Drift
- Computer Modeling
- Cadaver Dogs

TECHNOLOGICAL SEARCH

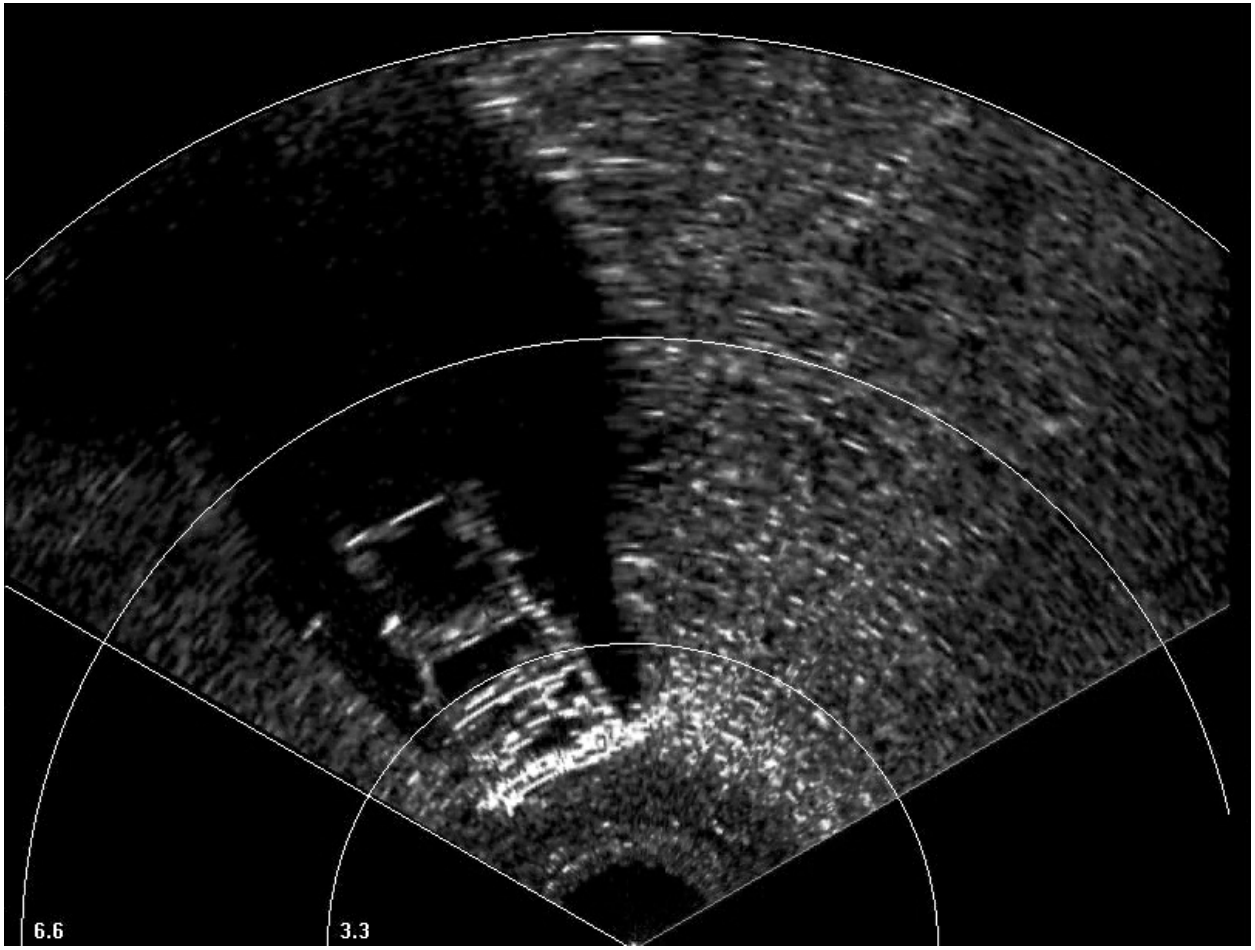
Visualization and photography of a body on the bottom of a pool using polarizing filter.





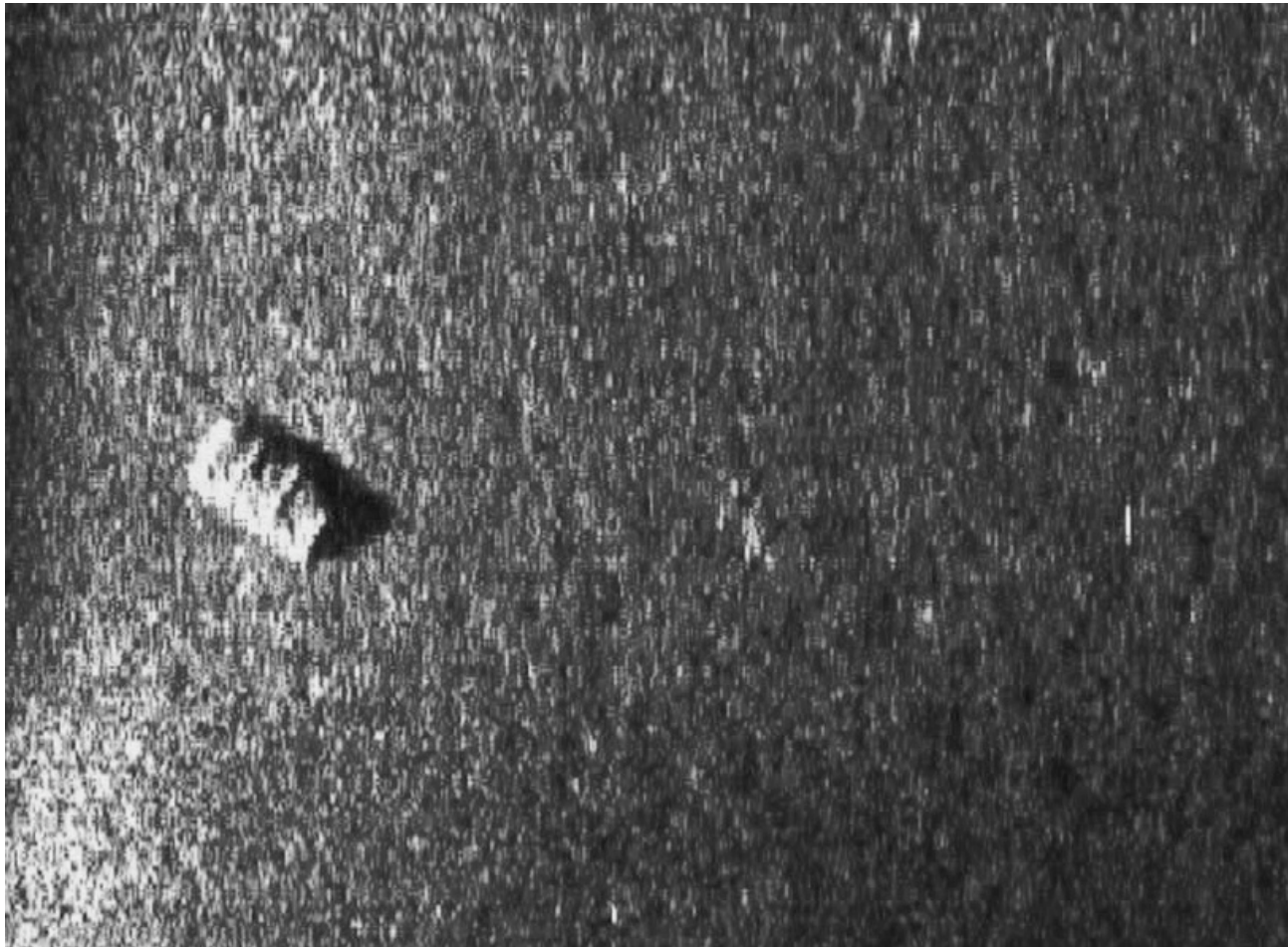
Scanning sonar view of a body on the bottom of a pool.

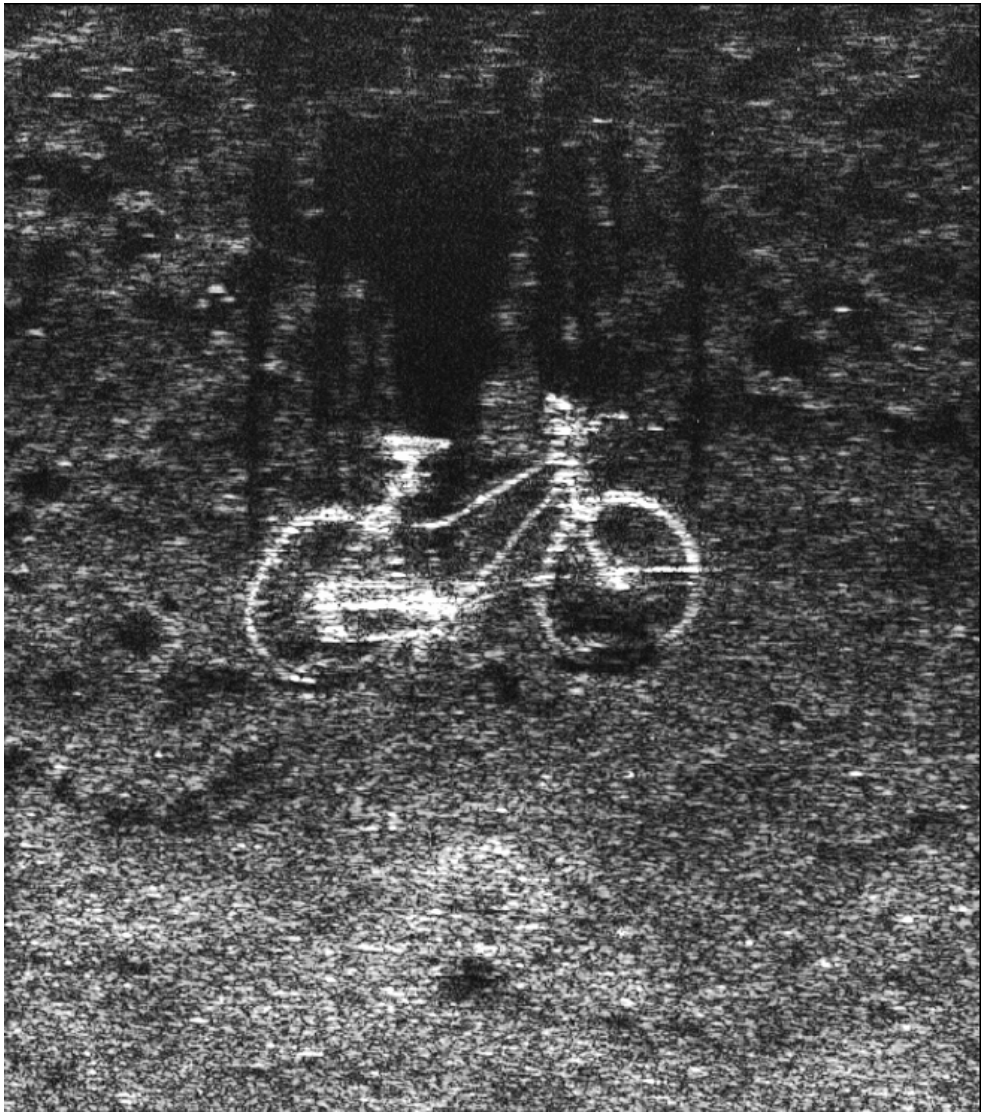
Scanning sonar view of a submerged automobile



Tow Fish

Submerged 55 gallon drum imaged with side scanning sonar.





Tow Fish

Submersible Guided Video Platform

RECOVERY OF HUMAN REMAINS


FML

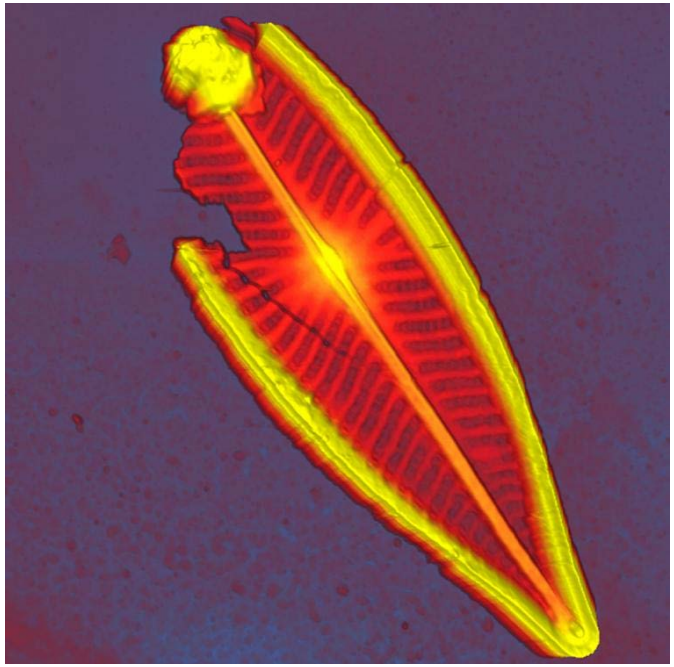
Processing the Body

- Note location and depth of body.
- Note if body was snagged, resting on the bottom etc…
- Move to a level surface and place in an open body bag
- Use standard method to process body
- Collect a sample of the water
- If the body is in a submerged vehicle or container, fully photographically document while under water and during recovery process.
- Search area where body was discovered or believed to have entered the water for additional evidence.
- Take care with removing metal items from the water.

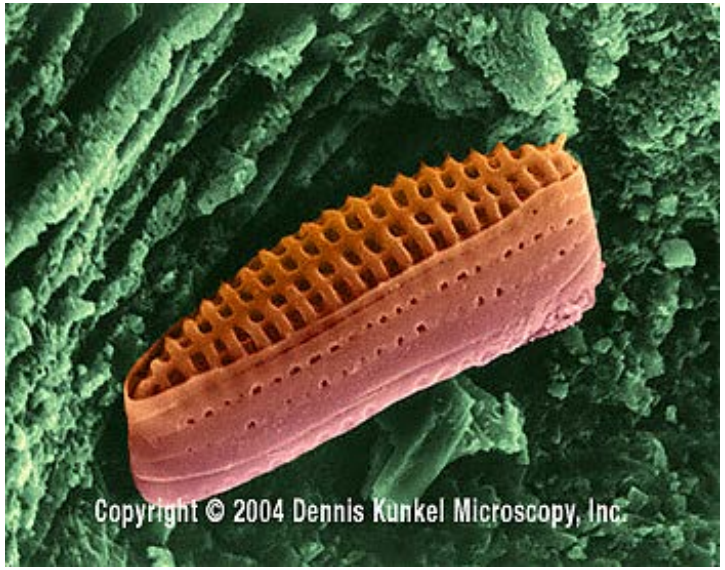
Expect Rapid Decompositional Changes upon Removal from Water

Remains Recovered from Predator

- Coordinate with ME to determine if bite injuries are premortem or postmortem
- Coordinate with a marine biologist to determine predators hunting area



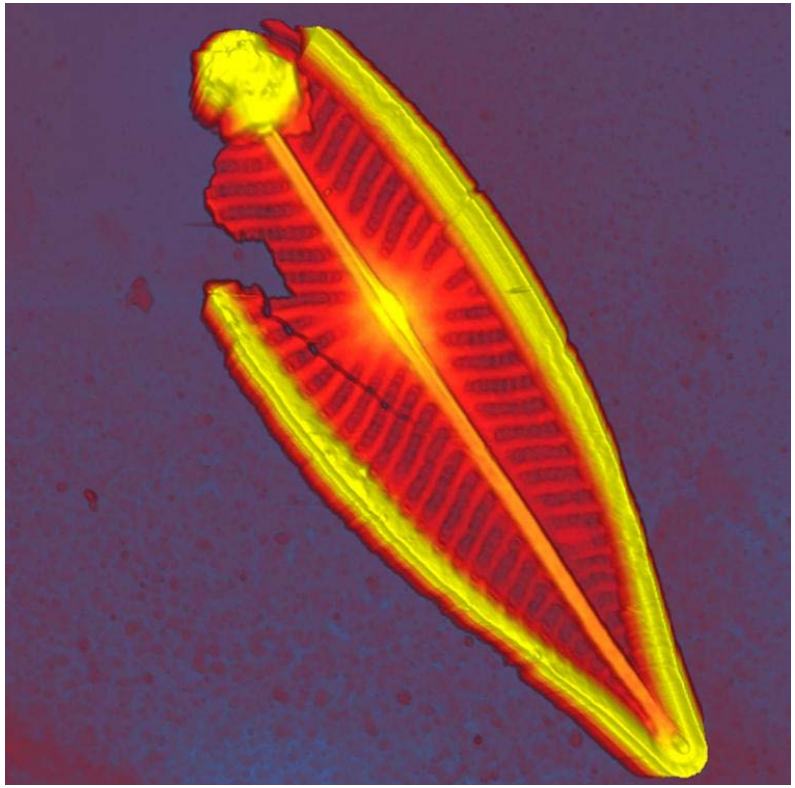
DIATOMS AS FORENSIC EVIDENCE



Diatoms

- Fresh and Saltwater
- Algae
- Most unicellular
- Cell wall made of silica
- Highly variable by body of water

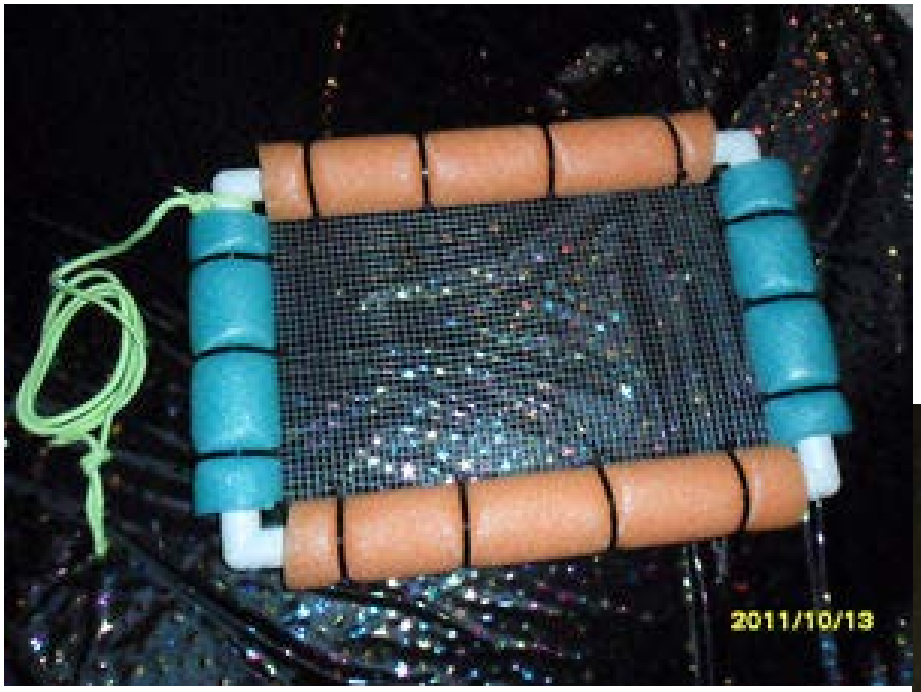
- Safe Insulation

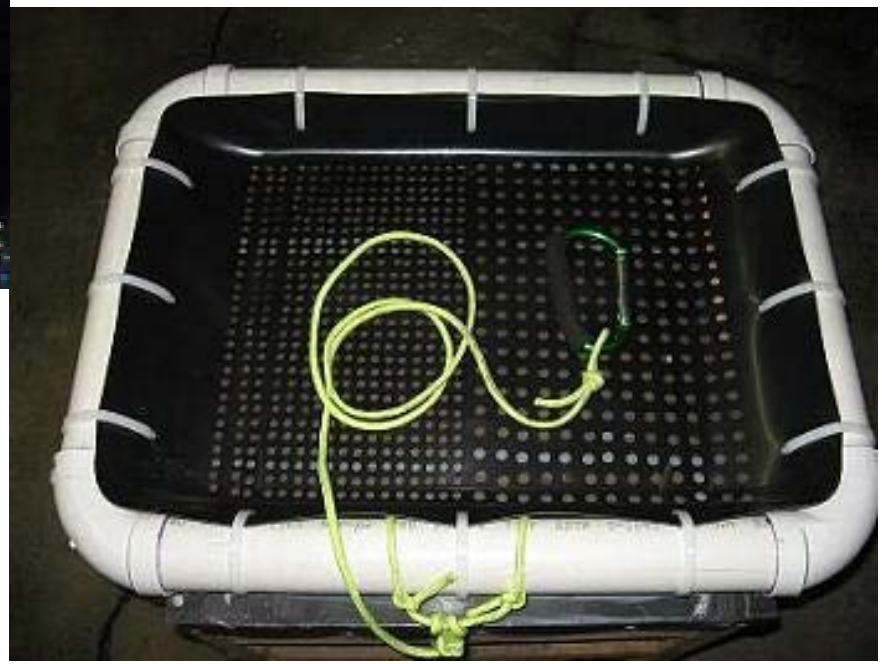


RECOVERY OF EVIDENCE

No! Bad Diver!

Floating Water Sieve





Evidence Recovery Protocol

- Search - Discover
- Mark
- Locate
- Document in Place
  - Notes – photography – sketching
- Water Sample: depth, temperature, clarity
- Recover – Water Sieve
- Safe
- Package
- Seal – ECD

Recovery of Evidence

- Note location and depth of evidence
- Photograph evidence in its location
- Note its relative position in regards to other items of evidence
- Collect a sample of the water from depth in container large enough to hold the evidence
- Move evidence to a collection screen, do not expose to the air!
- If weapon, safe weapon on collection screen and package
- Seal container, evidence seal, date/time/initials
- Log evidence

Expect Rapid Decompositional Changes upon Removal from Water

Documentation of Evidence

- Notes
- Photography
- Sketching

- How critical is its location?
- How Critical is its Position?