PVSS Conference

Hypothermia, Drowning and Cold-Water Survival

By

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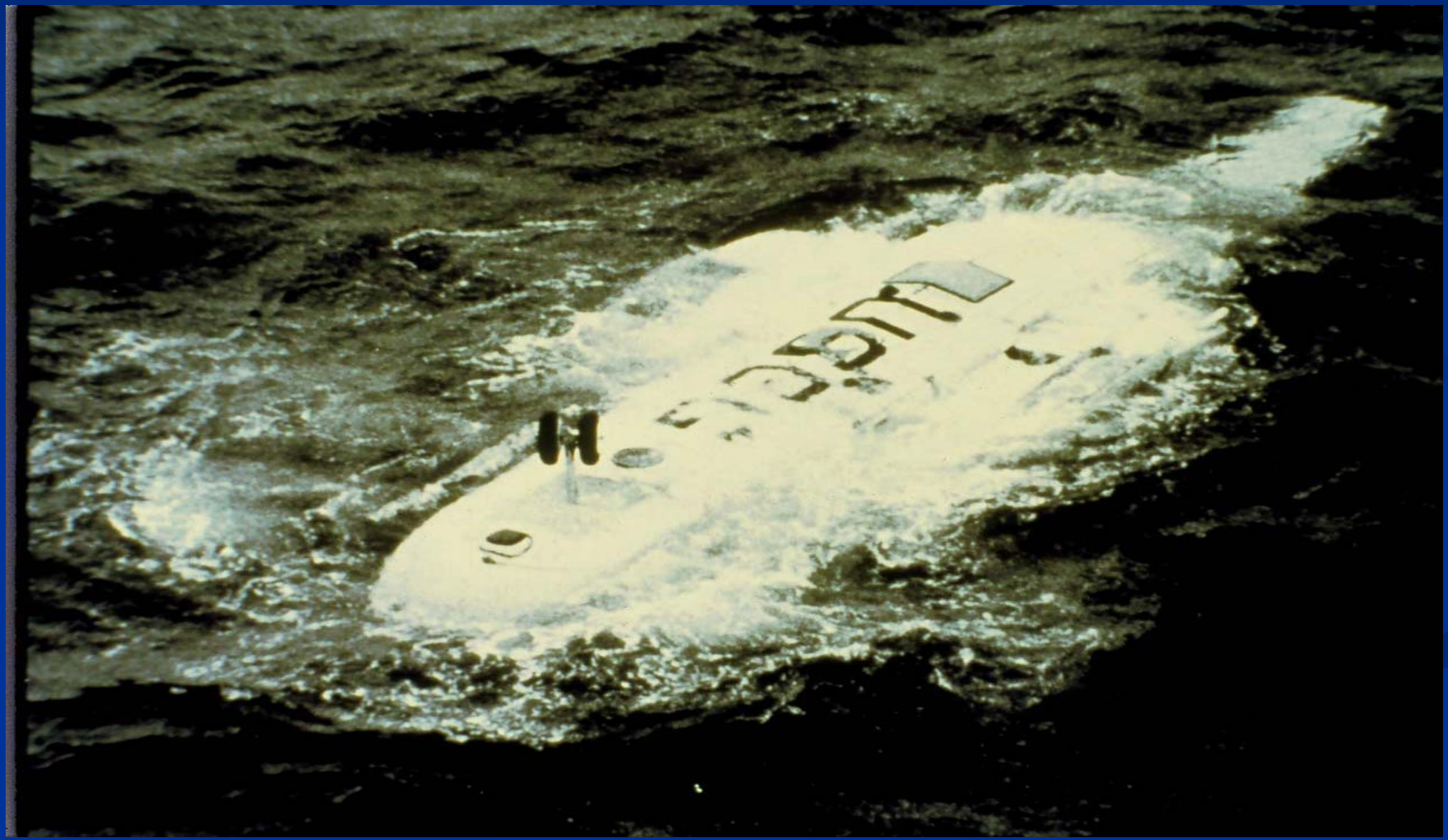
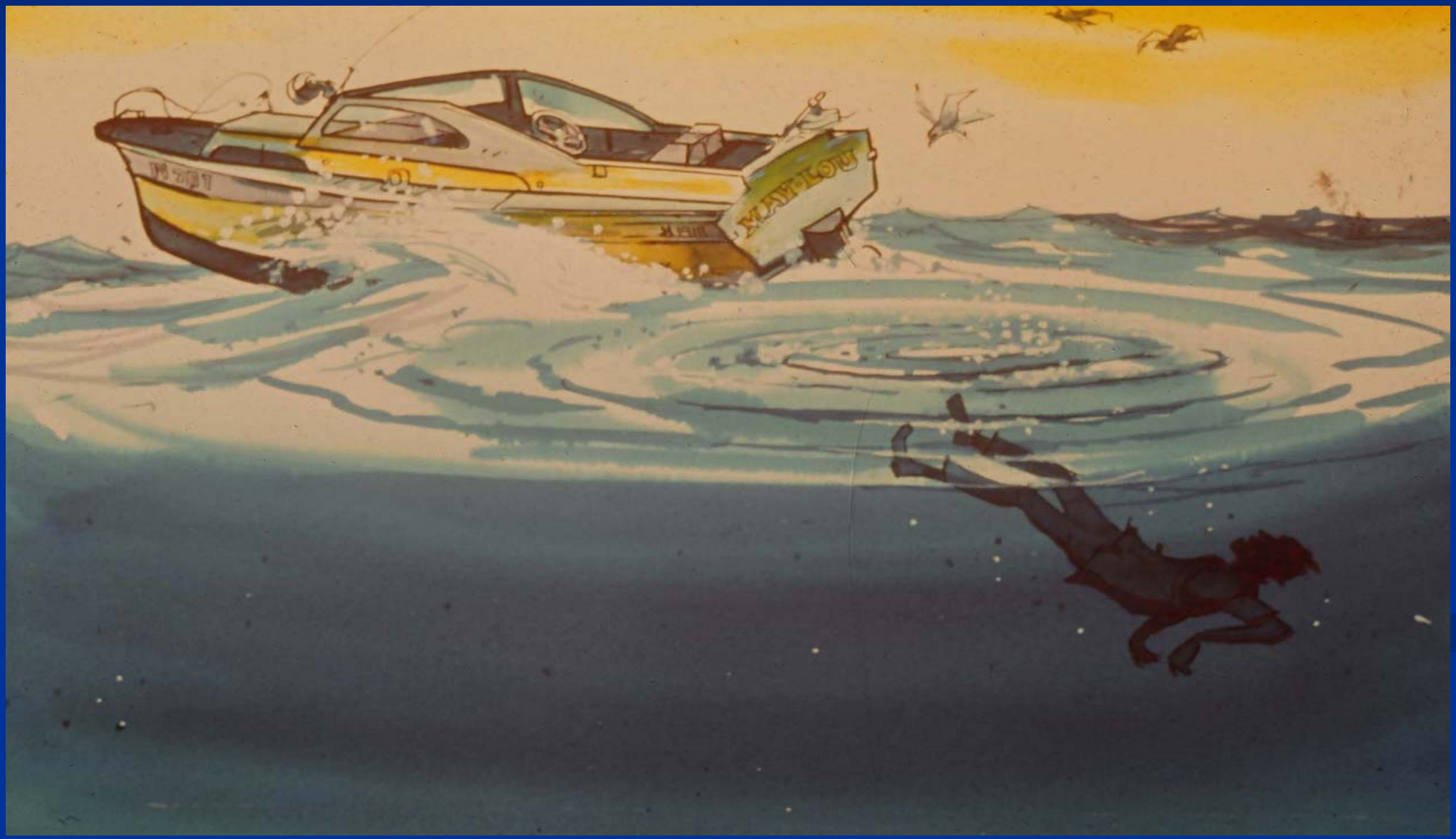
Disasters at Sea

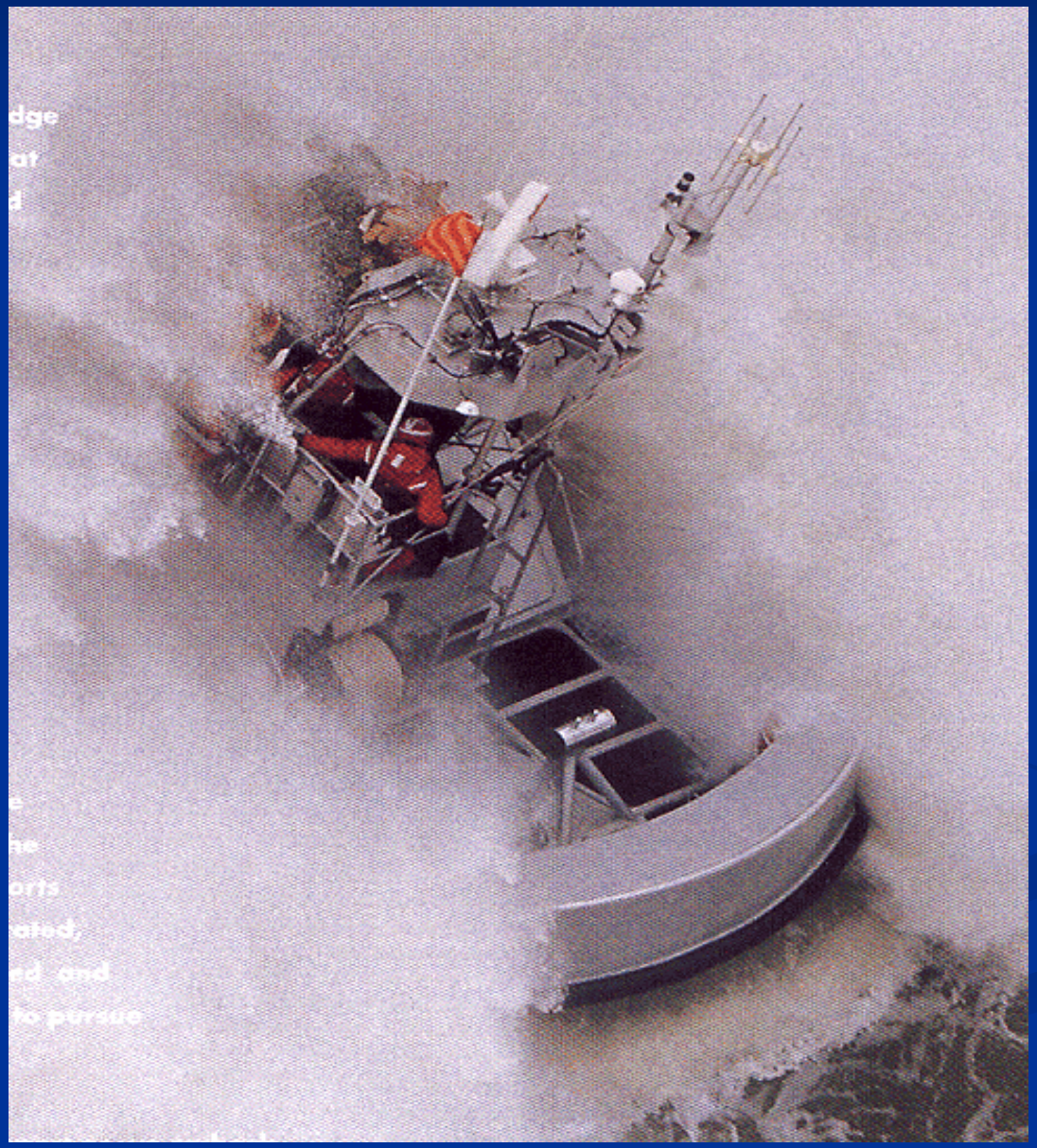
Aircraft Ditching at Sea



Falling Overboard



Washed Overboard

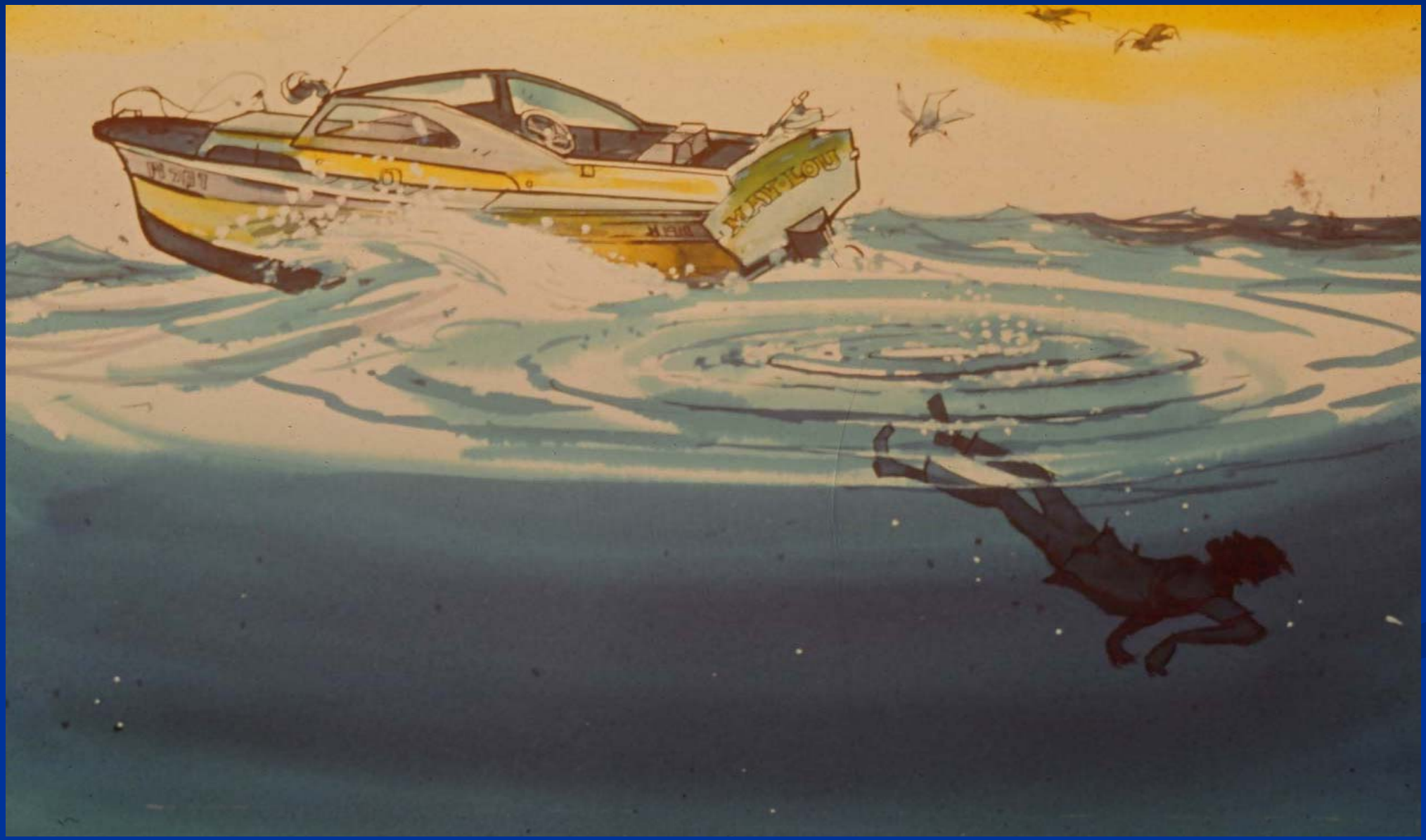


Understand Cold Exposure:
Immersion vs Submersion

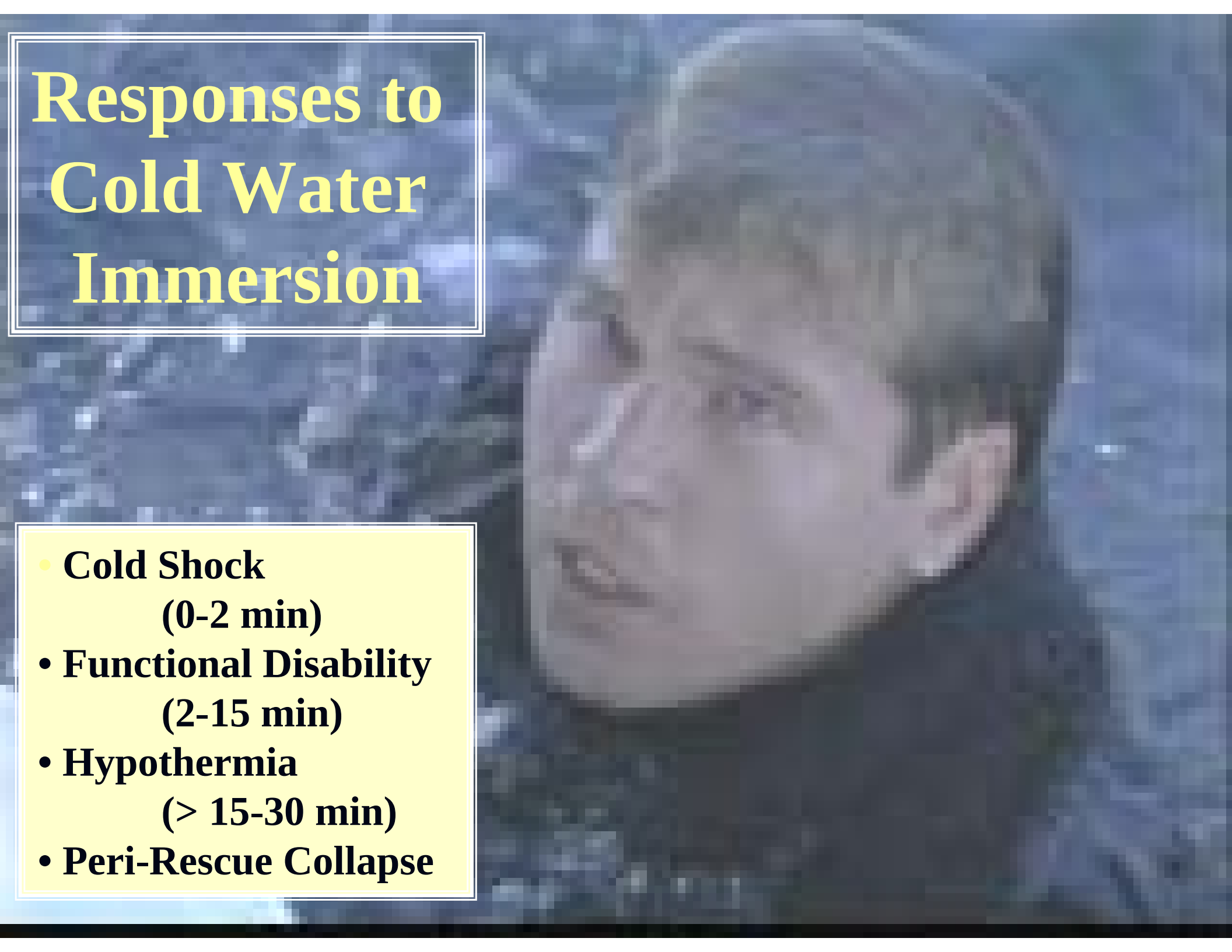
Immersion - Head Out!


Submersion = Head In !!

Physiological Responses to Sudden Immersion in Cold Water



Responses to Cold Water Immersion



- **Cold Shock (0-2 min)**
- **Functional Disability (2-15 min)**
- **Hypothermia (> 15-30 min)**
- **Peri-Rescue Collapse**

Cold-Shock Response

- Occurs immediately upon entry
- Lasts up to 2 minutes
- Caused by stimulation of truncal skin nerve endings
- The colder the water, the stronger the response

Cold-Shock Response

- Gasp reflex
- Hyperventilation
- Difficulty holding your breath
- Tachycardia (rapid heart rate)
- Hypertension (elevated blood pressure)

When and How You Can Die in Cold Water

1) Cold Shock Response

(0-2 minutes)

⇓

Gasp → Drown — **(Keep head out of water)**

⇓

Hyperventilation → Faint
→ Drown — **(Don't panic, keep calm)**

⇓

↑ Cardiac Work → Cardiac Arrest — **(If existing heart problems)**

Incapacitation in Cold Water

- Difficulty swimming
- Loss of functional ability
- Increased viscosity of cold water
- Loss of manual dexterity
- Muscle cramping
- Swimming speeds onset of hypothermia

When and How You Can Die in Cold Water

Local Cooling Decreases Performance Or Functional Disability

(2-15 minutes)

- **If you can't get out in 5-15 minutes, you might not get out on your own power!**
- **If so, prepare to survive.**
- **Widen window of opportunity for rescue.**
- **Thrashing around will**
  - **increase heat loss**
  - **cause exhaustion (Drowning)**

When and How You Can Die in Cold Water

Onset of Hypothermia

(>30 minutes on)

- Cooling to UNCONSCIOUSNESS
- If head goes under,

  Drowning (30-120 minutes).

- If head above water…
- Cooling to CARDIAC ARREST,

  Death (90-180 minutes or more, depending on water temp, body size, etc.)

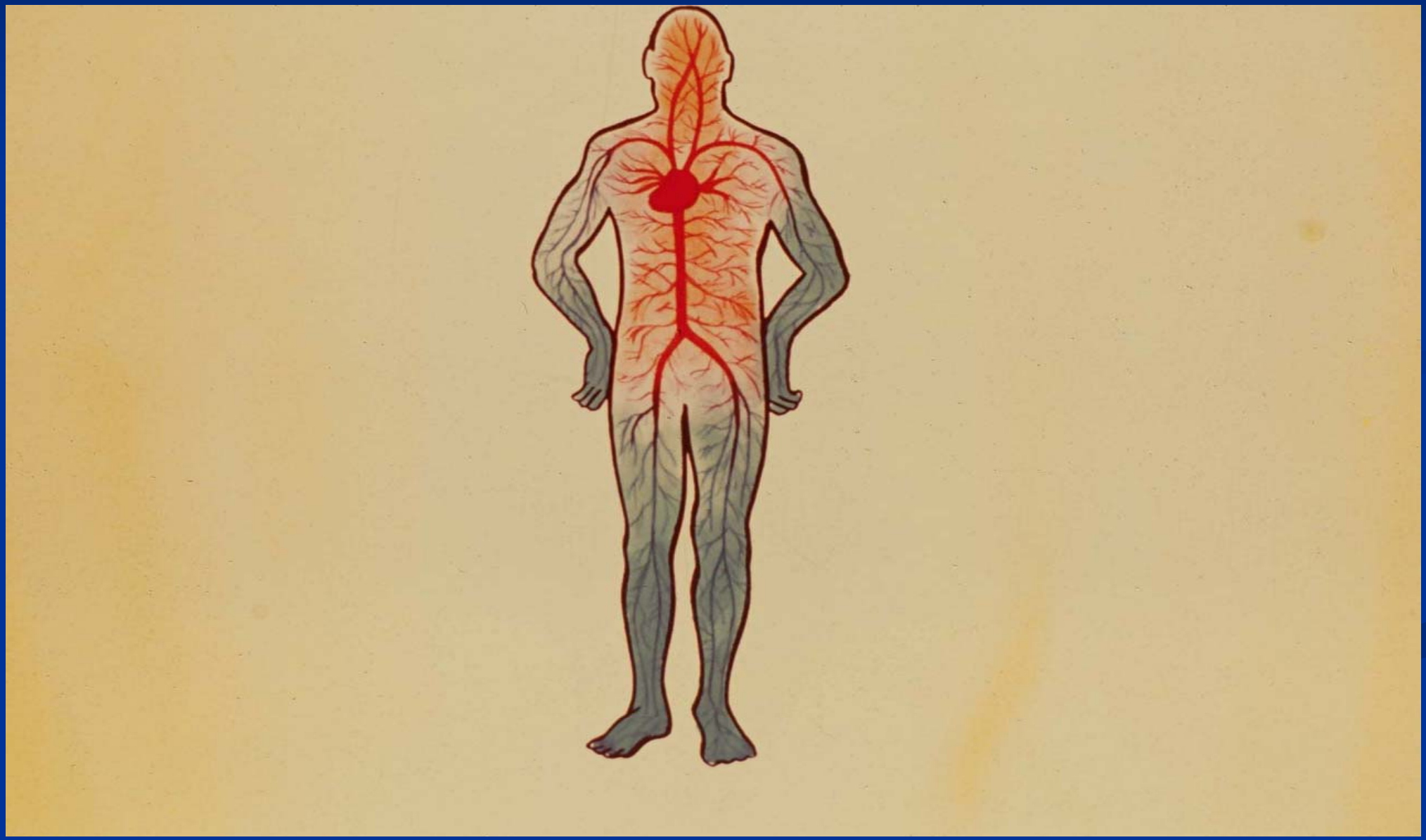
Summary of Cold Water Risks

- Cold Shock (0-2 minutes)
- Functional disability (2-30 minutes)
- Hypothermia (>30 minutes)

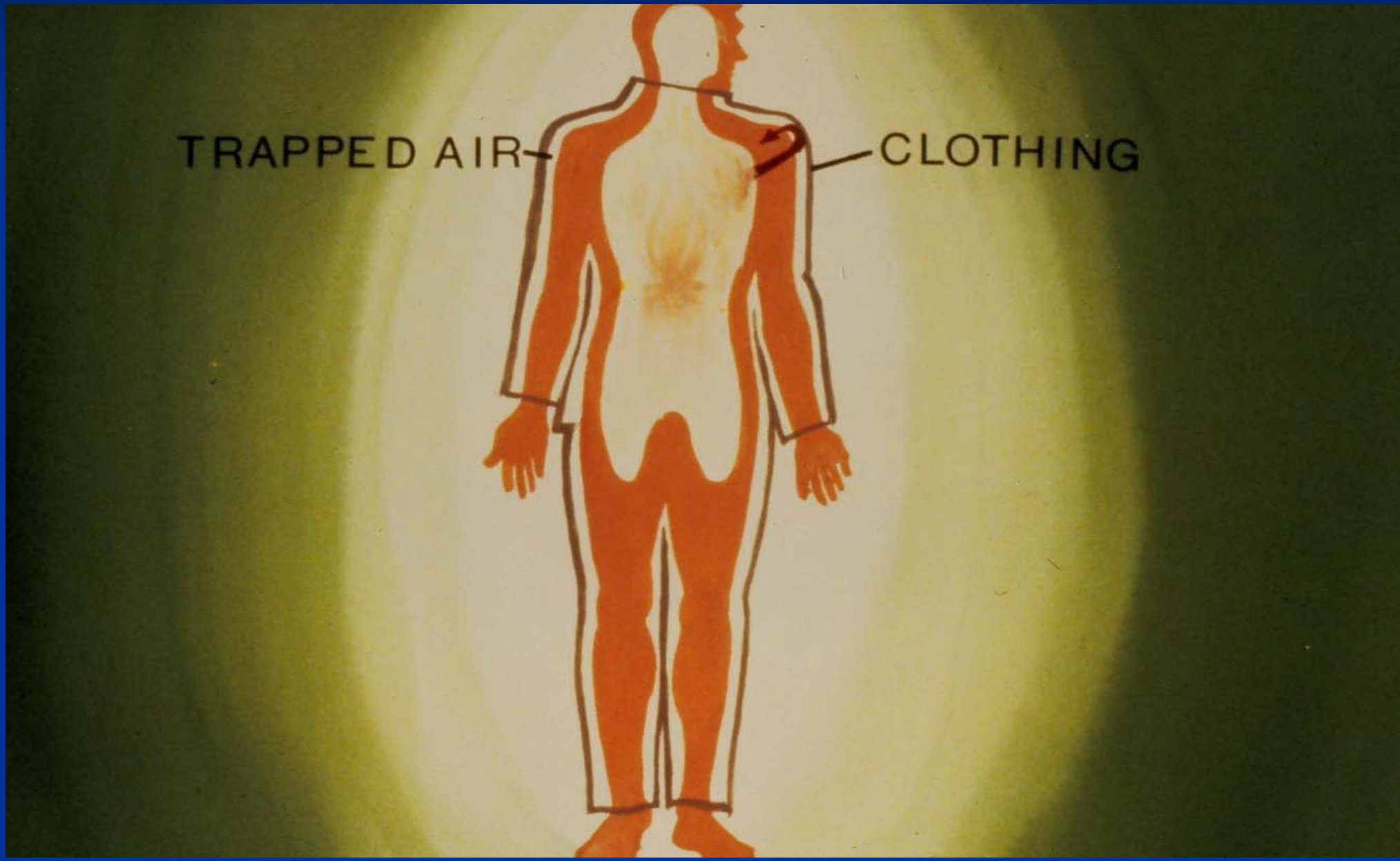
Role of Flotation

- PFDs, immersion suits, etc. can assist in surviving cold-shock & swim failure
- Rough seas remain a significant risk, even with flotation assistance
- Immersion suits can assist in prevention of hypothermia, if properly donned

Hypothermia in Cold Water



Air is an Excellent Insulator



Body Fat is an Excellent Insulator

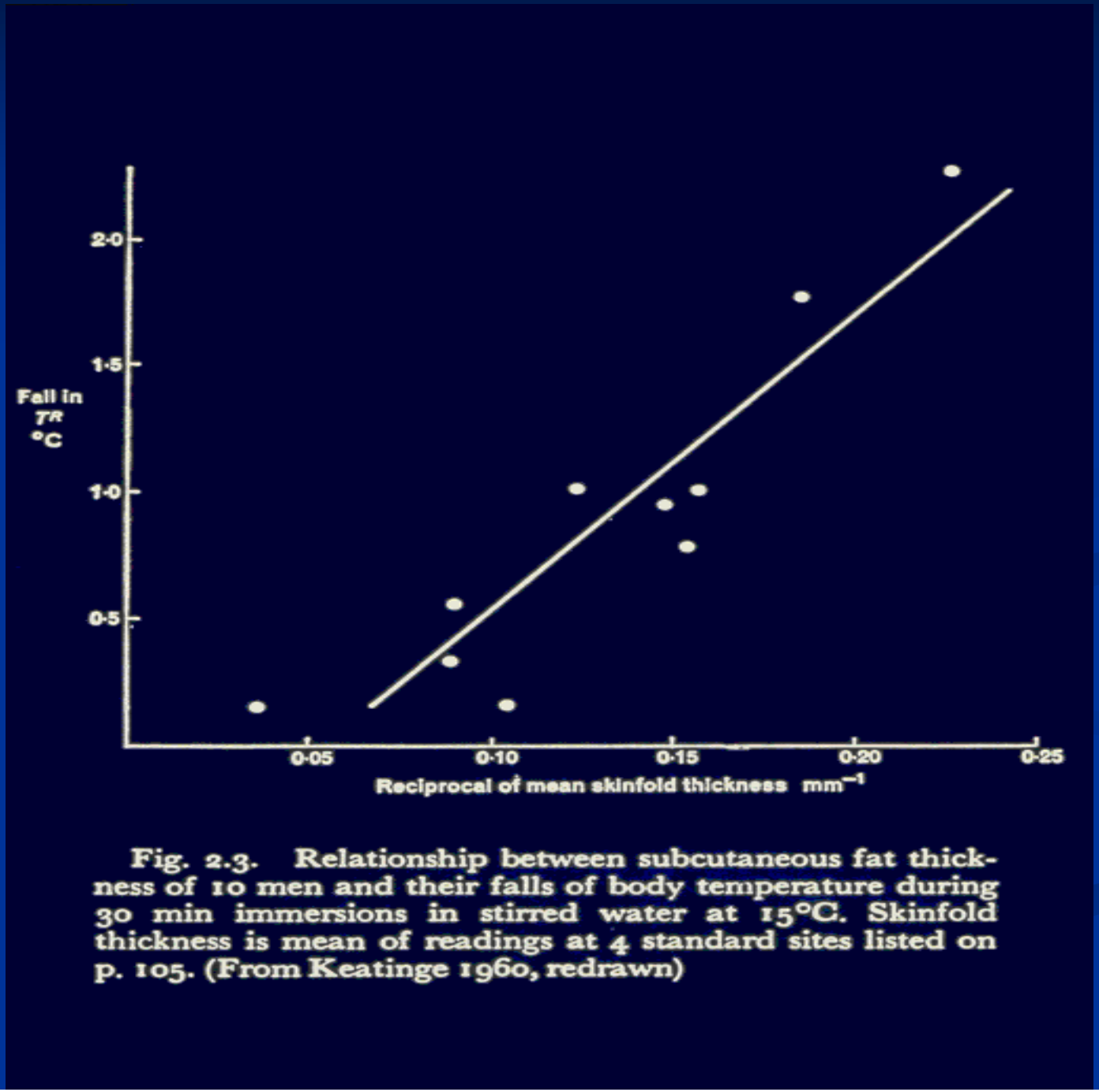


Fig. 2.3. Relationship between subcutaneous fat thickness of 10 men and their falls of body temperature during 30 min immersions in stirred water at 15°C. Skinfold thickness is mean of readings at 4 standard sites listed on p. 105. (From Keatinge 1960, redrawn)

Heat is lost from the body in proportion to its surface area

Large, fat people cool far more slowly than do small, thin or lanky people

Adults cool more slowly than do children

Hypothermia results when more heat is lost from the body than is produced (through metabolism and shivering) and retained (through body-fat, clothing, and behavioral adaptation).

Water is an Excellent Conductor of Heat

Physiology of Hypothermia

- Hypothermia defined as core temp < 95 deg F.
- Every organ system is affected (e.g., similar to multiple trauma)

Physiology of Hypothermia

- Constriction of surface blood vessels
- Cold sensation and shivering
- Physical impairments (motor skills)
- Mental impairment
- Cold-induced urination

Physiology of Hypothermia

- Abnormal heart beats and slowing of the heart rate
- Declining blood pressure
- Decreased metabolism
- Cessation of shivering
- Loss of consciousness
- Ventricular fibrillation / Cardiac arrest

Classification of Hypothermia

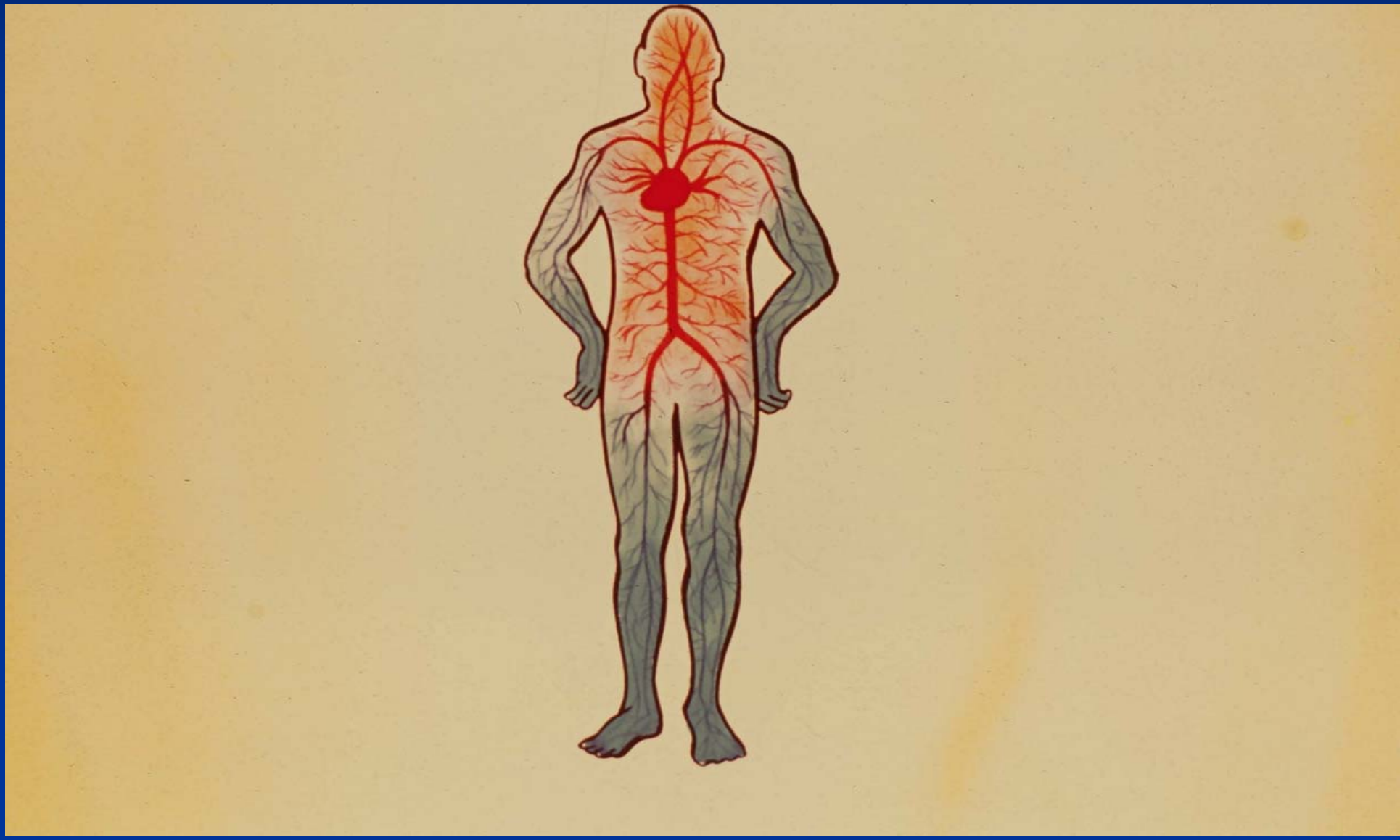
- 35-37 deg C: cold-sensation, shivering, constriction of surface blood vessels
- 32-35 deg C: Mild hypothermia; physical and mental impairments

Classification of Hypothermia

- **28-32 deg C: Moderate hypothermia**; cessation of shivering, abnormal heart beats, loss of consciousness

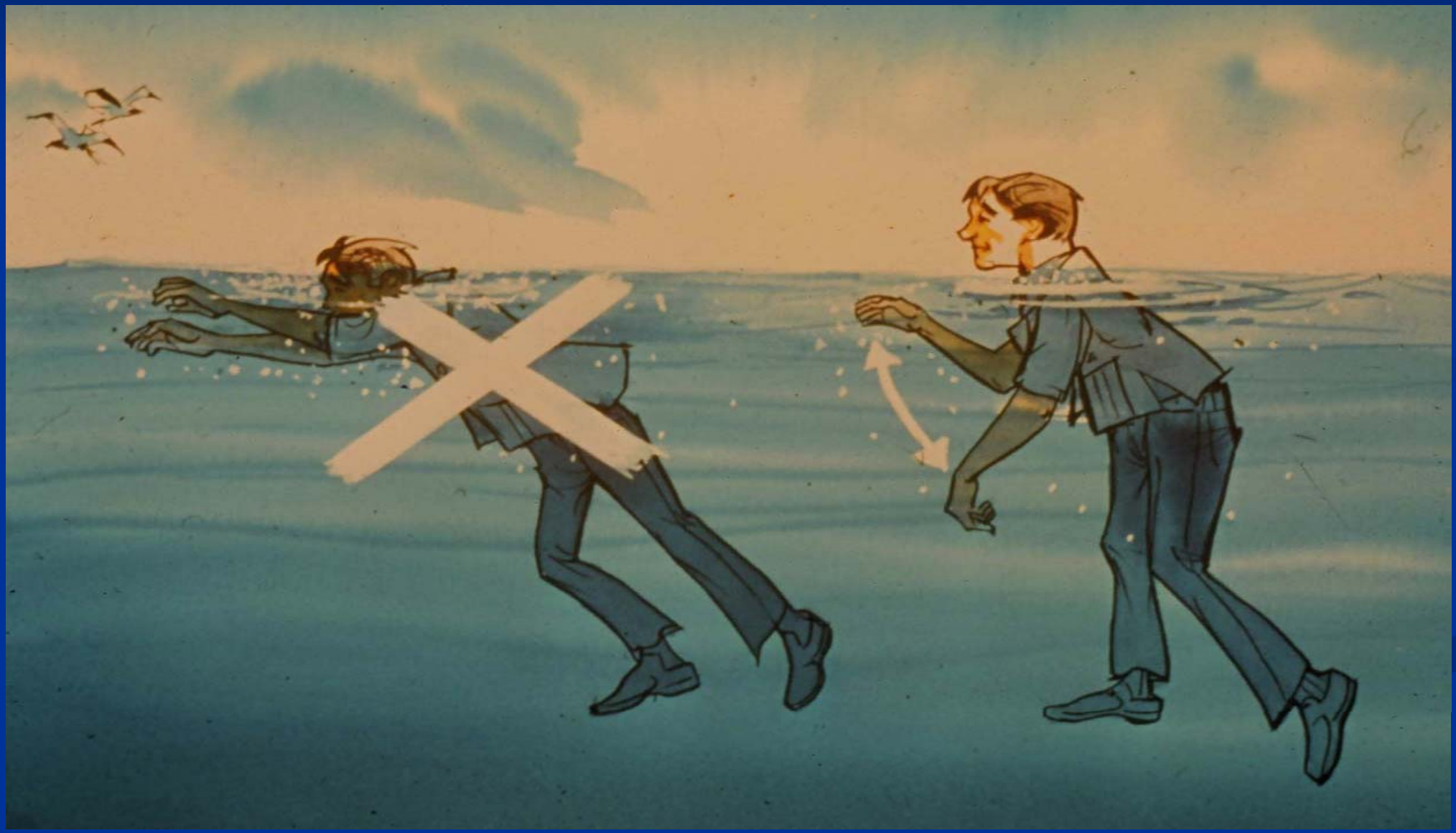
- **<28 deg C: Severe hypothermia**; vital signs reduced or absent; spontaneous ventricular fibrillation or cardiac arrest

Blood Vessel Constriction on Immersion in Cold Water



High Heat Loss Areas in Hypothermia

Do NOT Drownproof

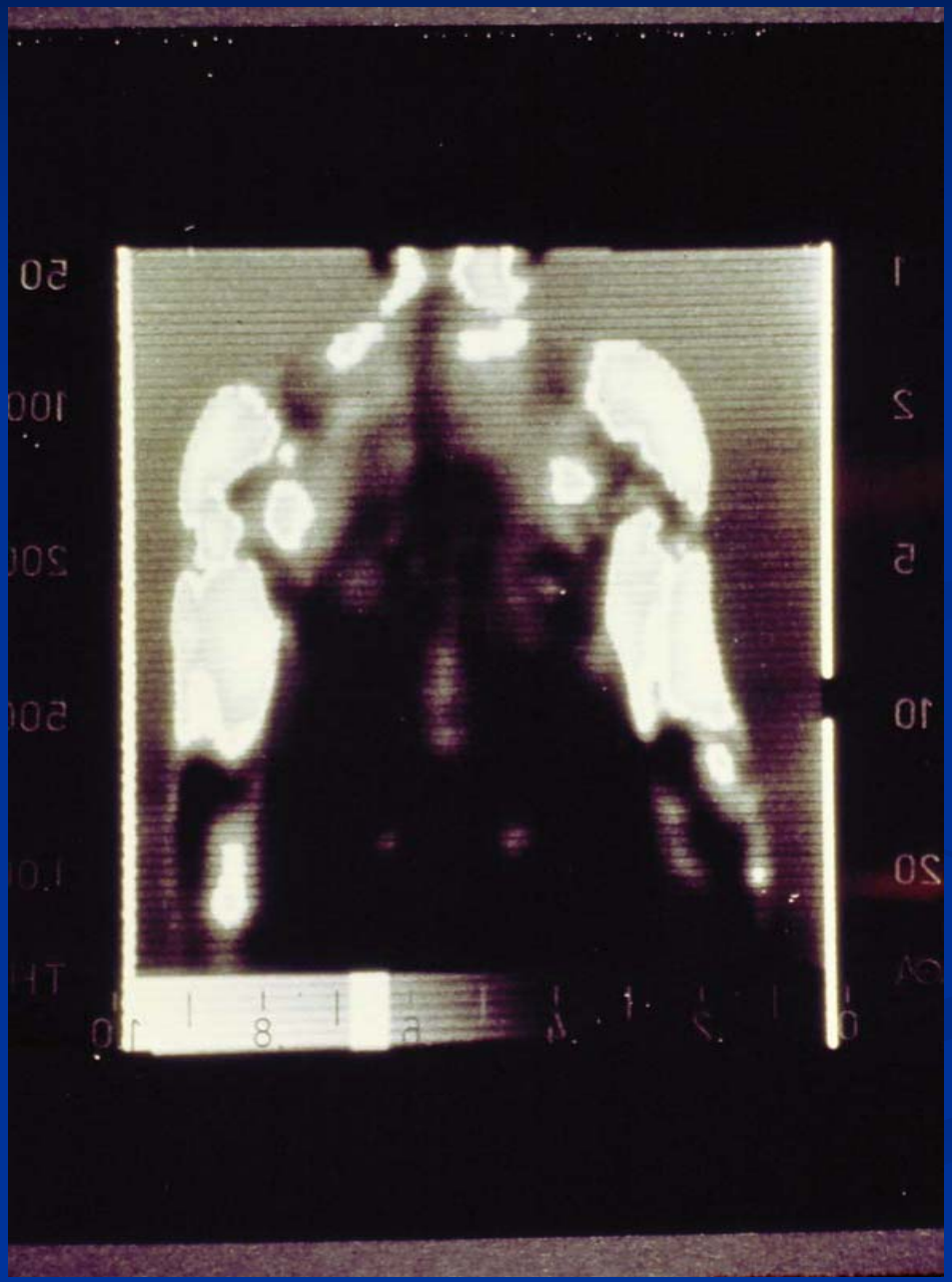


HELP Position

Huddle Technique

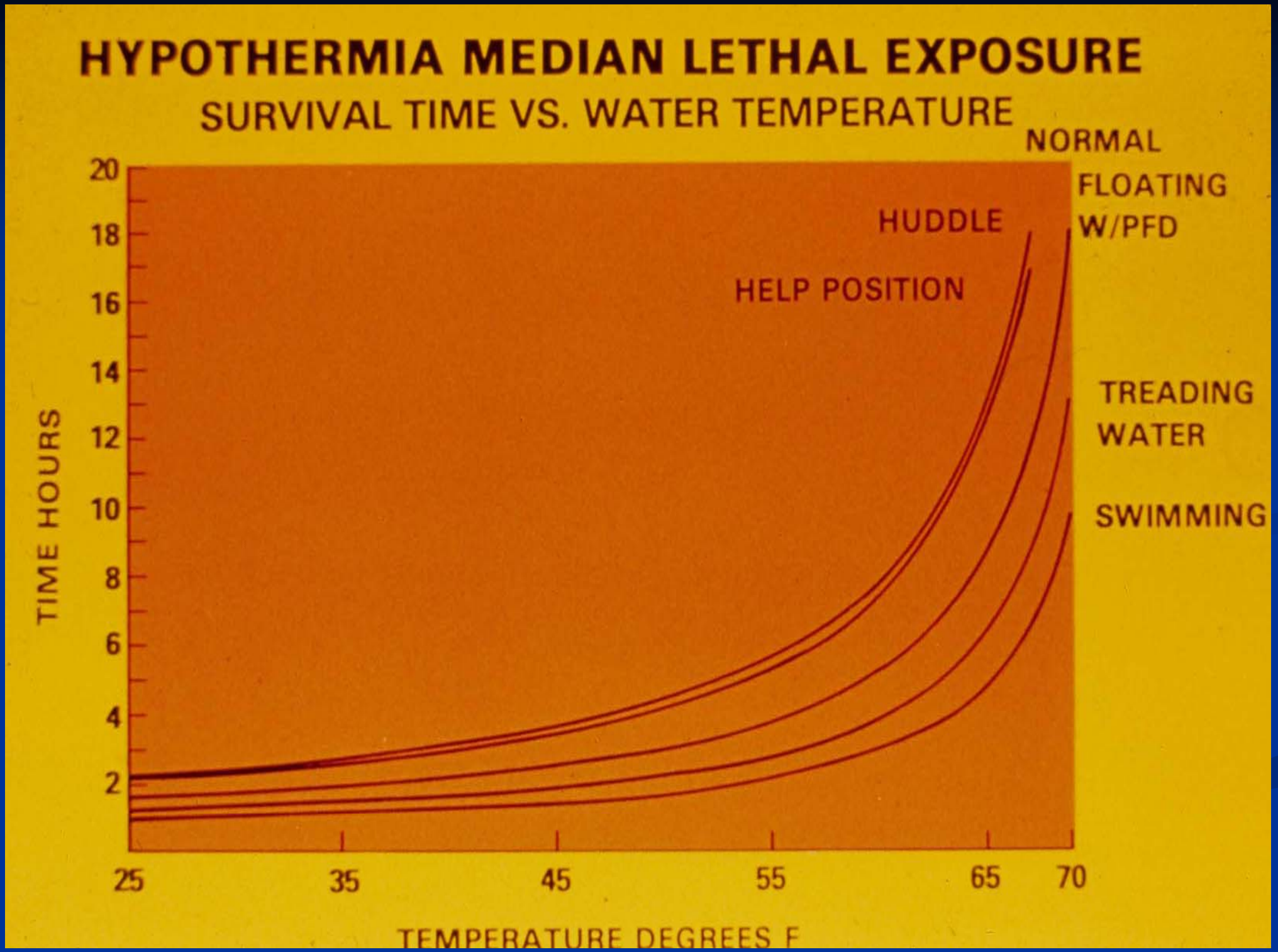
Should you Swim for Shore?

Heat Loss Areas After Swimming in Cold Water



HYPOTHERMIA MEDIAN LETHAL EXPOSURE

SURVIVAL TIME VS. WATER TEMPERATURE



Physiology of Drowning

- Loss of breath-holding ability
- Aspiration of water
- Coughing, violent struggle to reach surface
- Laryngospasm (vocal cord constriction)

Physiology of Drowning

- Low levels of oxygen
- Loss of consciousness
- Reflex swallowing
- Ventricular fibrillation
- Death

Pathophysiology of Drowning

- Submersion in cold-water is associated with a significantly higher survival rate
- Rapid cooling of the brain increases the ability to survive low oxygen levels
- Higher probability of successful resuscitation
- Even up to 60 minutes submersion!

Practical Applications of Studies in Cold-Water Immersion

Hypothermia Test Subjects

PHYSICAL CHARACTERISTICS OF THE EIGHT SUBJECTS

AGE	23.5	± 2.7
WEIGHT (KG)	71.7	± 3.7
HEIGHT (CM)	175.0	± 2.2
SKINFOLD THICKNESS (MM)*	9.9	± 2.0
% BODY FAT	11.1	± 2.6
$VO_{2(MAX)}$	49.7	± 6.0

* Mean of three sites: triceps, subscapular and abdominal

Rough Water vs. Calm Water Test Garments

- FS Flight Suit (control)
- BC Boat Crew Coverall (Stearns worksuit)
- AC Aircrew Coverall (Mustang worksuit)
- WS Full Wet Suit
- SWS Short Wet Suit
- FC Float Coat
- IS Immersion Suit
- DS Dry Suit (working deck suit)

Test Conditions

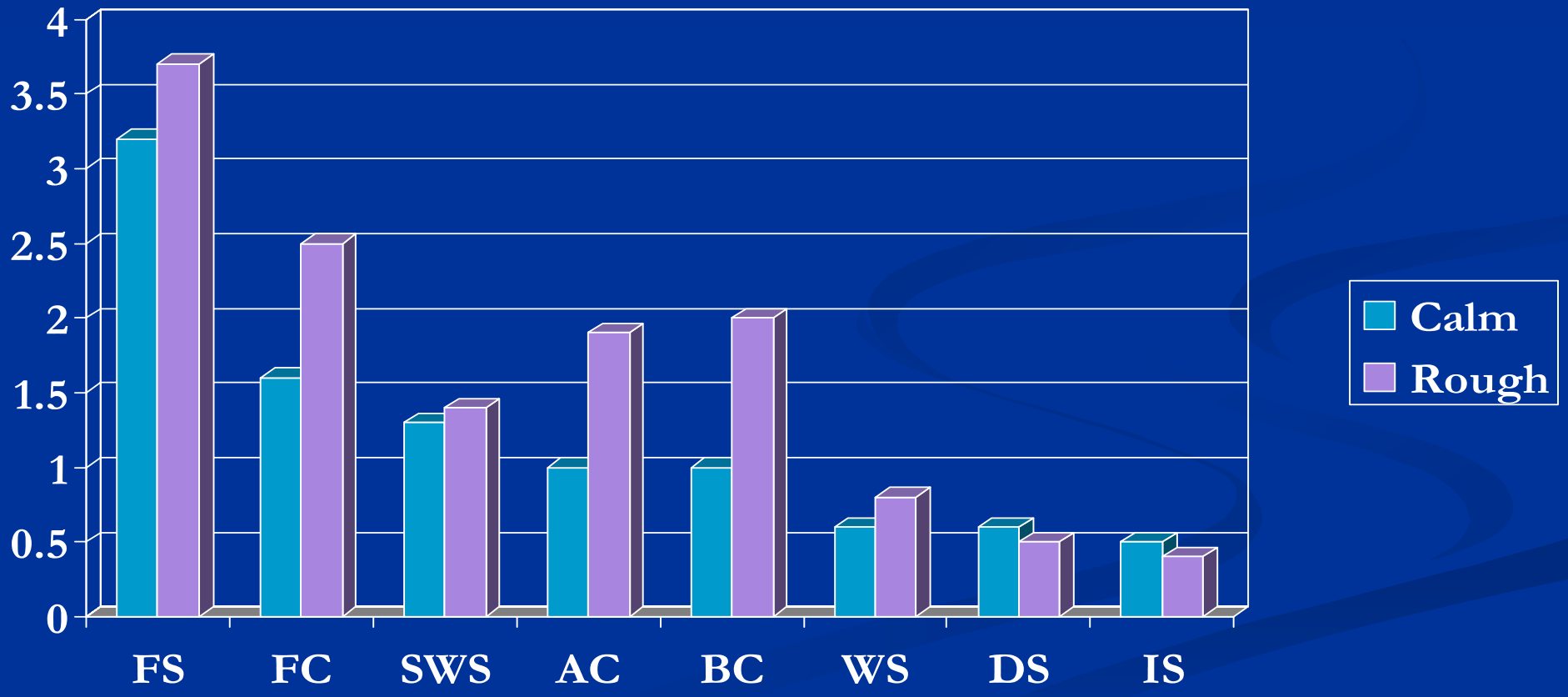
- 50 degree F. water
- Calm Seas – test performed at dockside
- Rough Seas – 4-6 ft waves every 30 secs;

Calm Water Test – 50 deg. F.

Rough Water Test – 50 deg. F.

Calm vs. Rough Water Results

Cooling Rates in degrees C. per hour



Survivor Location in Cold Water: Test Conditions

- Rough Seas - 5 foot breaking waves
- 43 deg. F. water 46 deg. F. air 15 knot wind
- Capsized boat
- Survivors in the water next to the boat
- Survivors atop the boat exposed to wind and waves
- Survivors in a one-person liferaft

What would you do?

Get out of the water, sit atop the boat, and thus be exposed to wind-chill and waves;

OR

Stay in the water, hang onto the boat, and thus be exposed to waves and cold-water

Test Garments

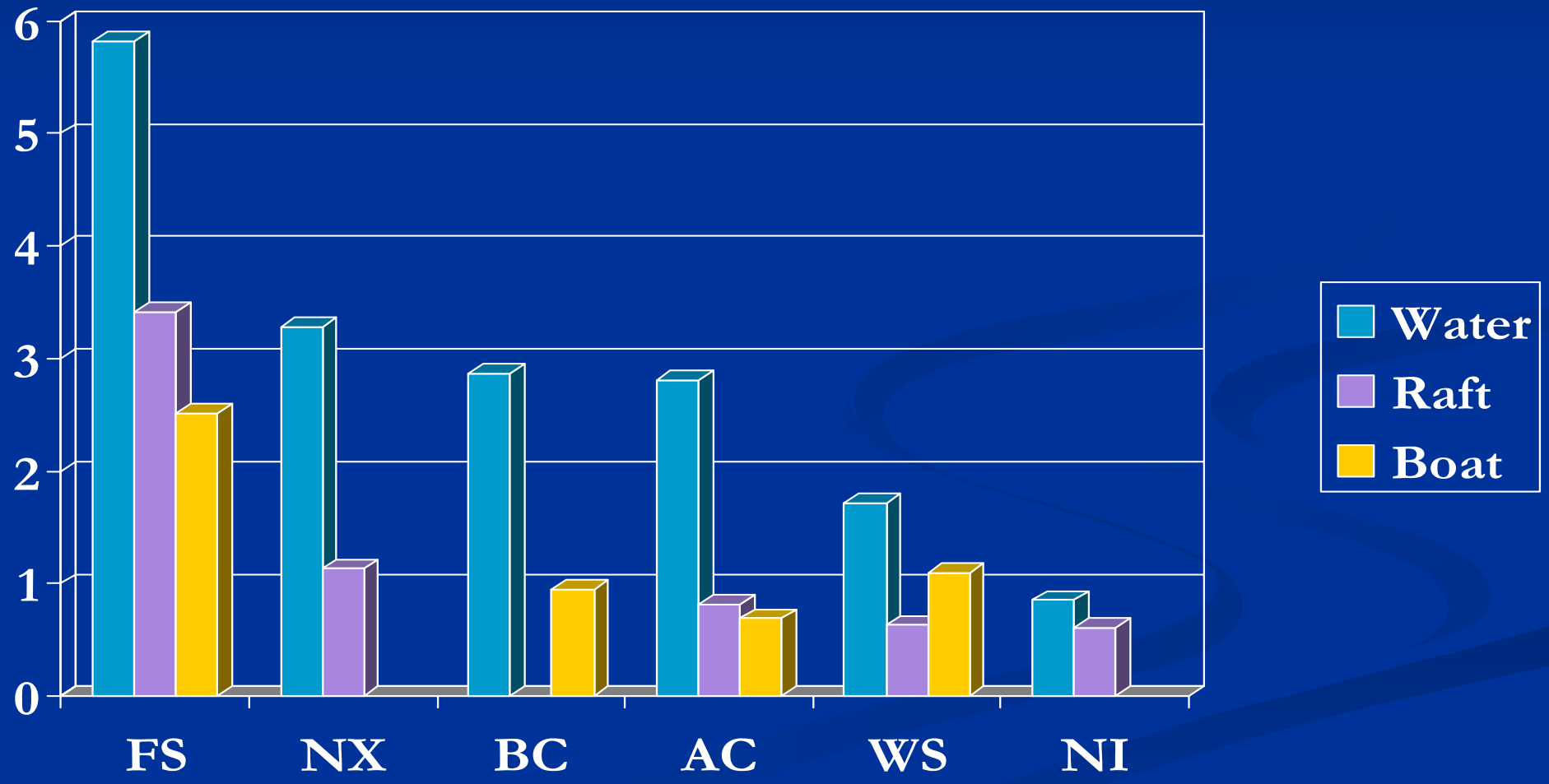
- FS Flight Suit
- WS Wet Suit
- BC Boatcrew coverall
- AC Aircrew coverall
- NI Navy flight ensemble – intact
- NX Navy flight ensemble -- torn

5 Ft. Break on a 20 Ft. wave

Test Garments

- FS Flight Suit
- WS Wet Suit
- BC Boatcrew coverall
- AC Aircrew coverall
- NI Navy flight ensemble – intact
- NX Navy flight ensemble -- torn

Cooling Rates, °C. per Hour



Take Home Lessons

- **Get Out of the Water !!**
- **No matter what the weather conditions, you're almost always better off out of the water**
- **Water is a great conductor of heat**

Take Home Lessons

- **Air is a great insulator**
- **Windchill is vastly over-rated as a risk**
- **Get Out of the Water !!**

Head Cooling Study

- The head has always been suspected of being an area of high heat loss.
- No previous studies to measure it.
- Some PFDs can be worn such that the back of the head is immersed.
- Does this lead to more rapid cooling and thus a shorter survival time?
- Does head cooling impact mental processes?

Head Cooling Study

- 2 PFDs – one worn with the back of the head immersed, (head in, body in); one worn with the head out of the water (head out, body in).

- Controls: dry suit with the head protected (head out, body out); dry suit with the back of the head immersed (head in, body out)

Head Cooling Study

Four permutations of head and body immersion:

Head in, body in

Head in, body out

Head out, body in

Head out, body out

PFDs

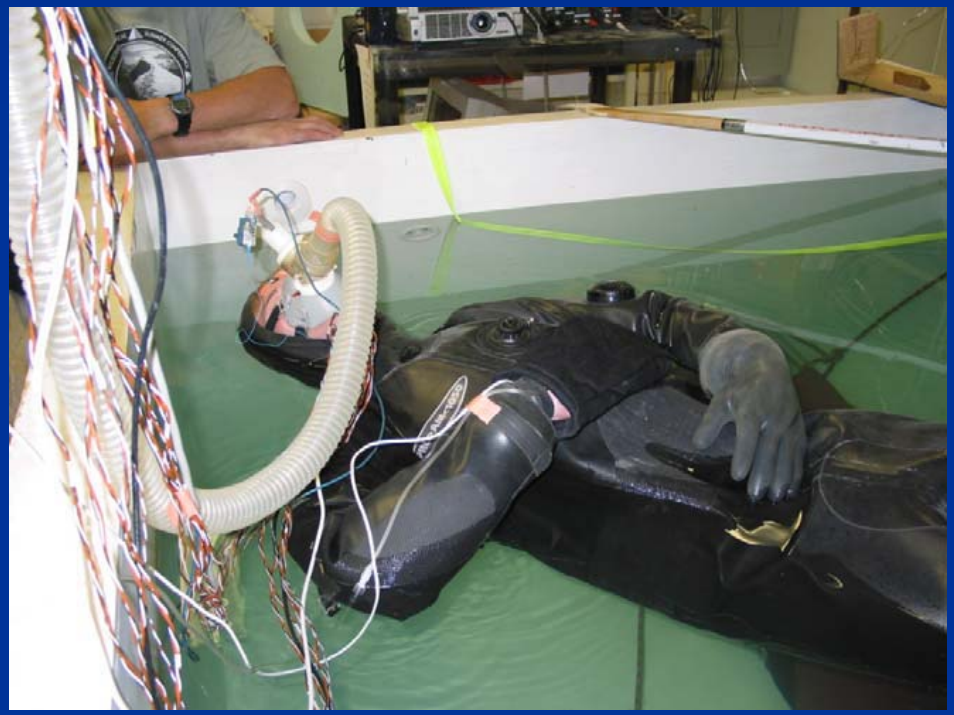
PFDs

PFDs in 10 Deg C (50 Deg F) Water

Head In, Body In

Head Out, Body In

Dry Suit in 10 Deg (50 Deg F) Water



Head Out, Body Out

Head In, Body Out

Head Cooling Results

Drop in Core Temperature (Deg. C)
After One Hour

Head Out, Body Out:	0.1
Head In, Body Out:	0.4
Head Out, Body In:	1.4
Head In, Body In:	2.2

Head Cooling Results

The increased cooling rate was related to the increase in total body surface area immersed (dorsal head and neck and upper anterior thorax) rather than from increased heat flow through the head.

In other words, the head was NOT found to be an area of disproportionately high heat flow.

Head Cooling Results

There was a significant correlation between body core temperature and mental performance, when all the psychometric data were pooled:

Lower core temperatures produced poorer thinking.

Take Home Lessons

- The onset of hypothermia in water immersion is accelerated when the head is immersed.
- Head-cooling impacts thinking/judgment
- PFD designs should strive to prevent head immersion; survival protocols and training curricula should continue to emphasize head protection.

The End