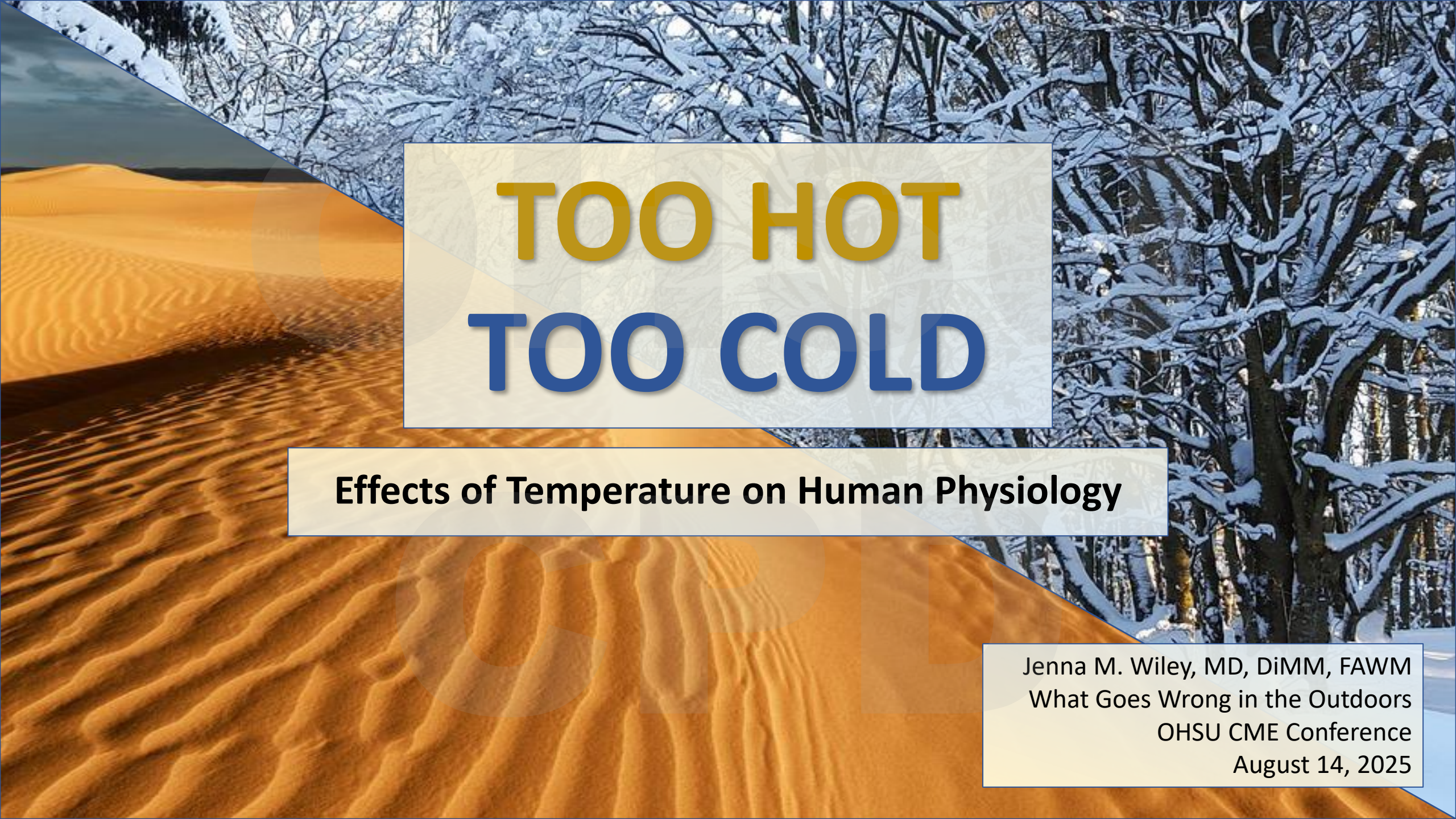
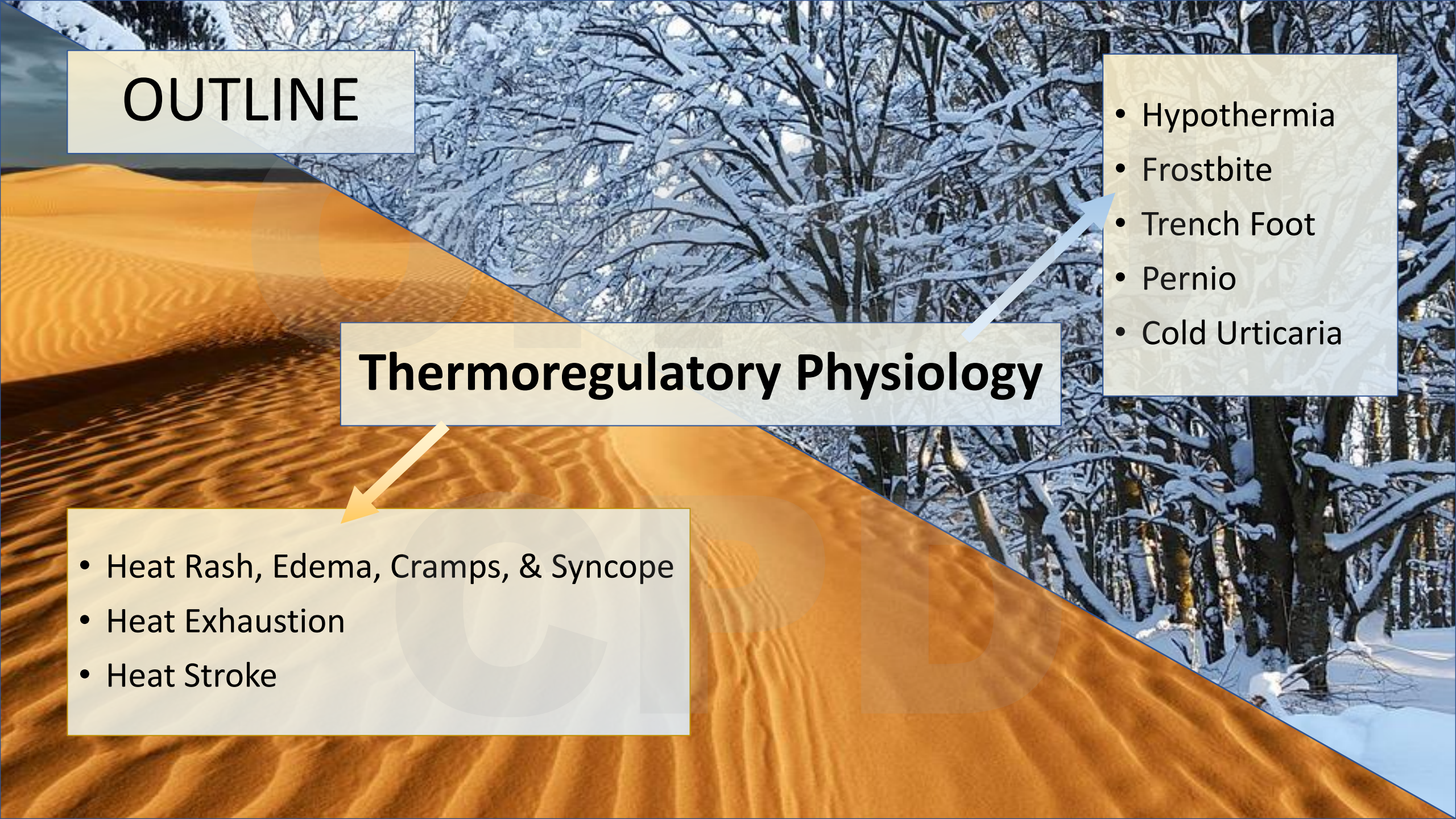


TOO HOT
TOO COLD

Effects of Temperature on Human Physiology

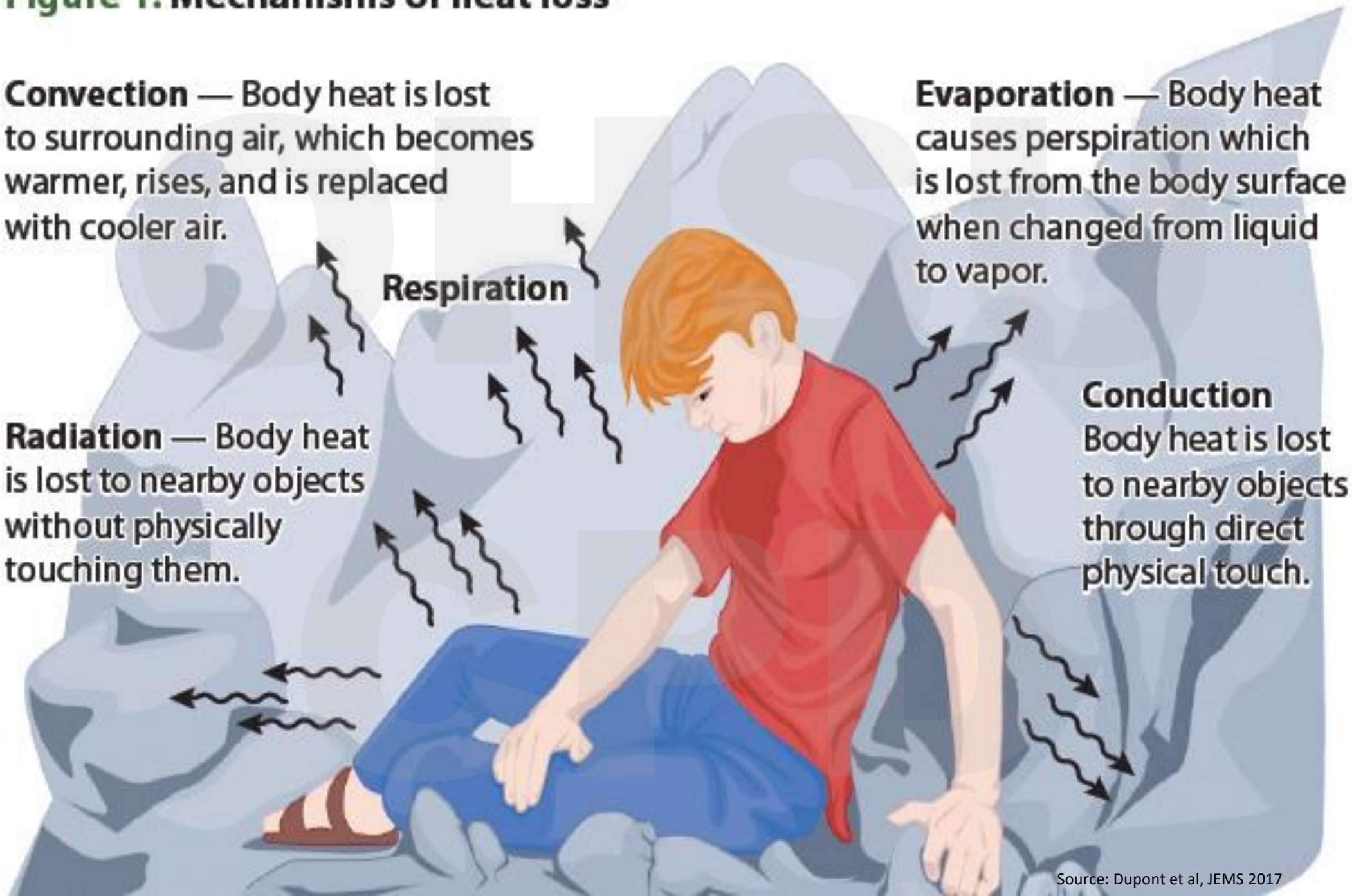
Jenna M. Wiley, MD, DiMM, FAWM
What Goes Wrong in the Outdoors
OHSU CME Conference
August 14, 2025


OUTLINE
Thermoregulatory Physiology
• Heat Rash, Edema, Cramps, & Syncope
• Heat Exhaustion
• Heat Stroke
• Hypothermia
• Frostbite
• Trench Foot
• Pernio
• Cold Urticaria

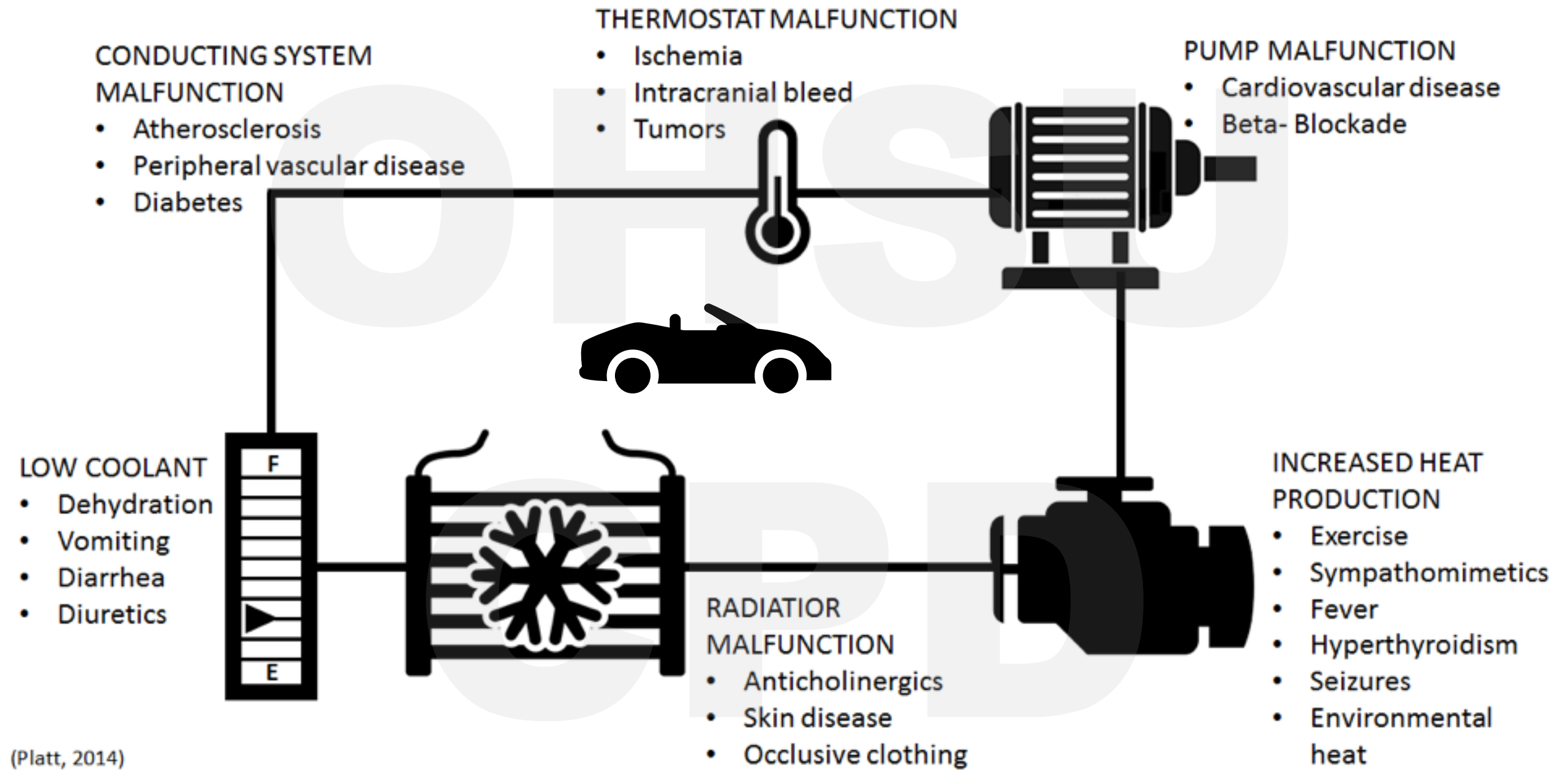
PATHOPHYSIOLOGY

Source: Medical News Today

Figure 1: Mechanisms of heat loss

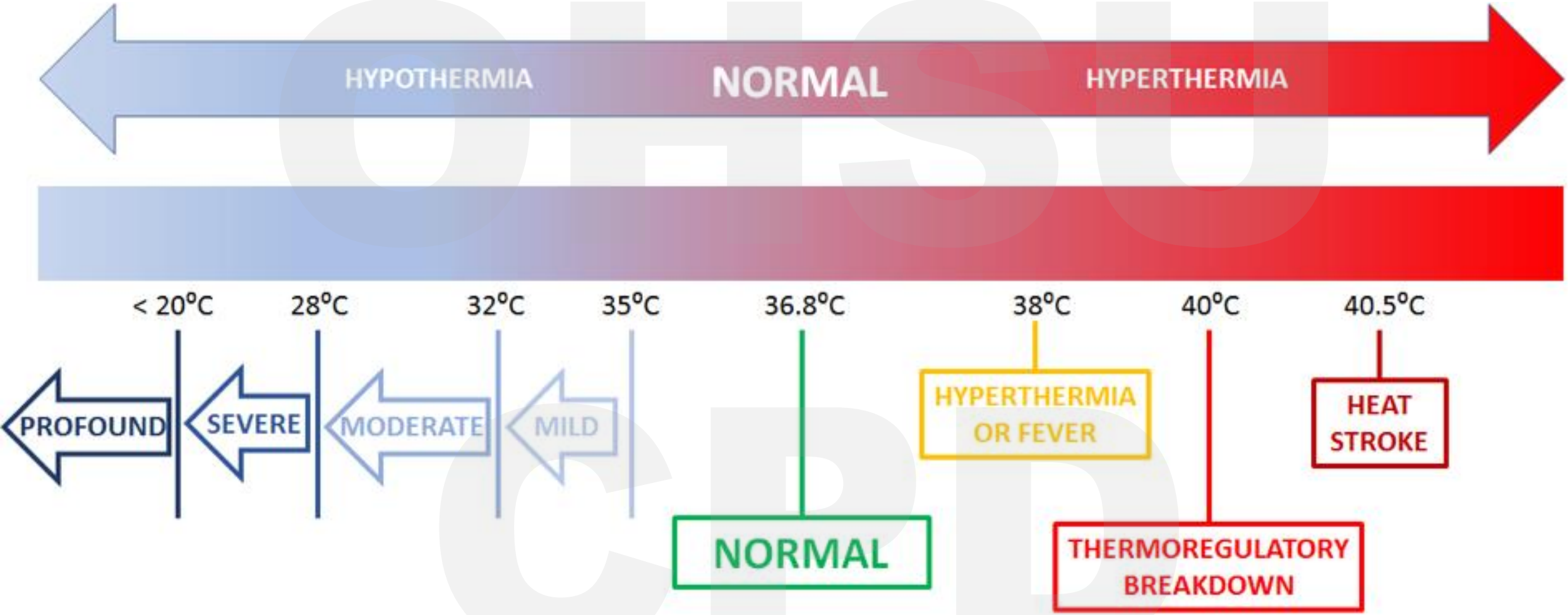


Source: Dupont et al, JEMS 2017

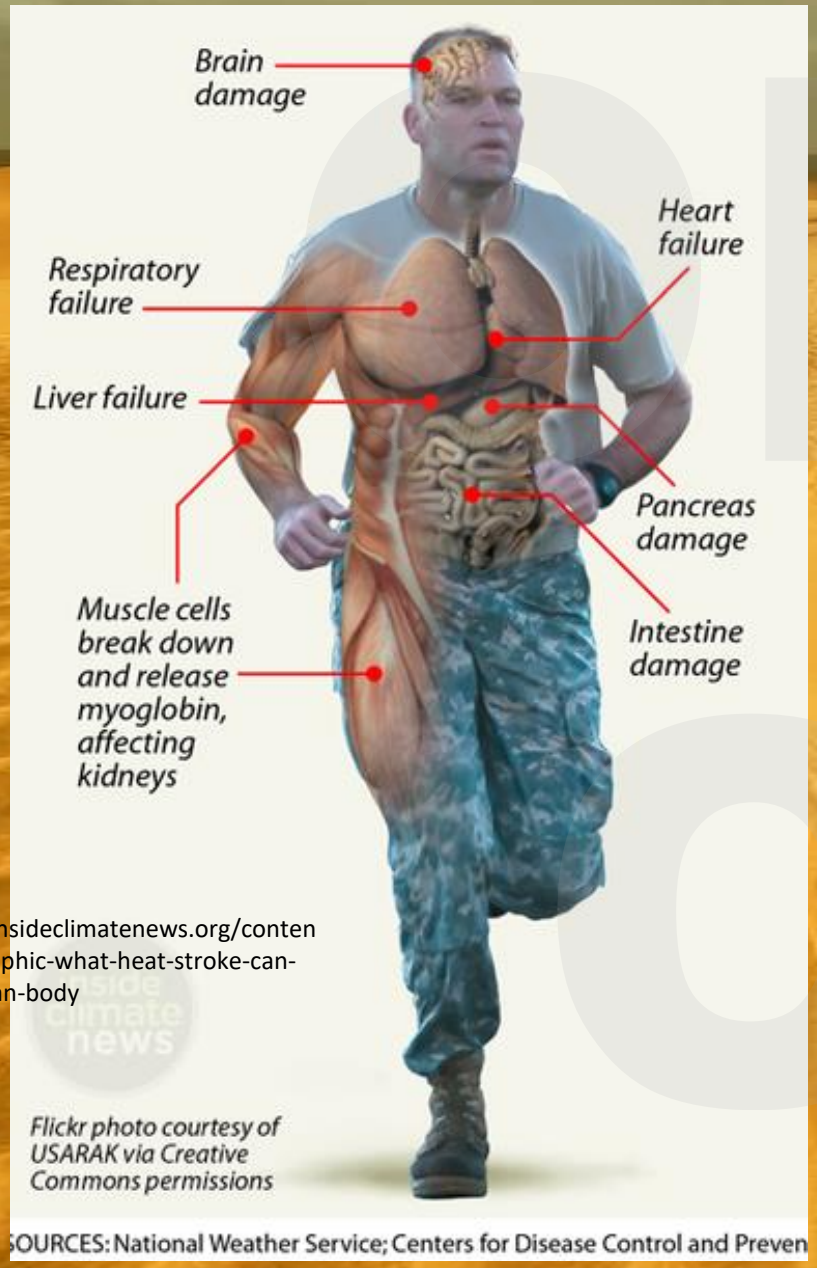


(Platt, 2014)

Source: http://sportmedschool.com/heat-related-illness/


HYPOTHERMIA
NORMAL
HYPERTHERMIA
< 20°C
28°C
32°C
35°C
36.8°C
38°C
40°C
40.5°C
PROFOUND
SEVERE
MODERATE
MILD
NORMAL
HYPERTHERMIA OR FEVER
THERMOREGULATORY BREAKDOWN
HEAT STROKE

HEAT STRESS



Source: https://insideclimatenews.org/content/infographic-what-heat-stroke-can-do-human-body

Protein denaturation → neuronal cell death
Distributive shock → hypoxic brain injury

Distributive shock → end organ ischemia → cardiac collapse
Demand ischemia (increased CO) → cell death → hyperkalemia

Hyperventilation, hyperpnea, pulmonary vasodilation → ARDS

High vascular permeability → GI bleeding
Hepatic ischemia → liver cell apoptosis → cytokine release

Dehydration → hypoperfusion → acute renal failure

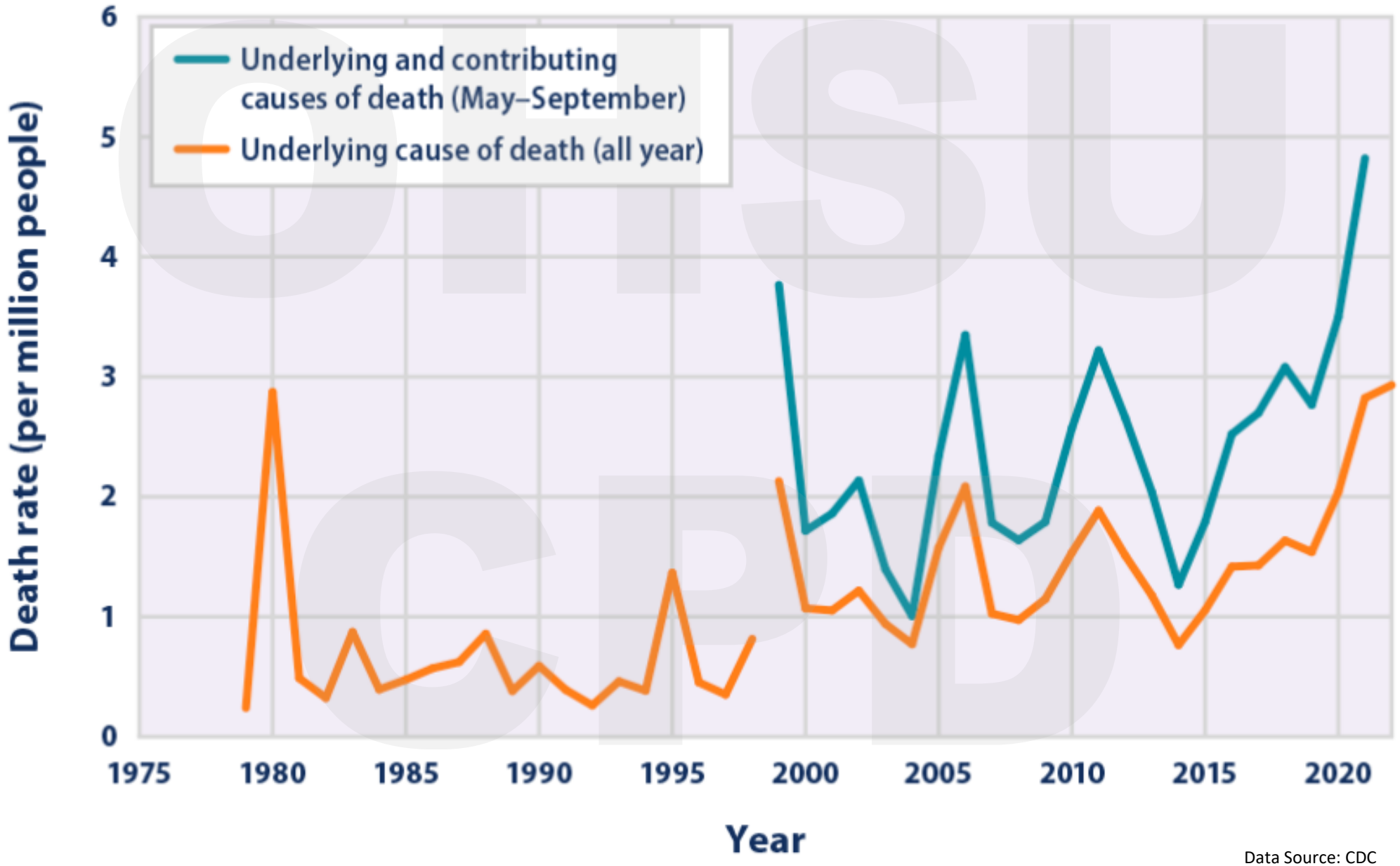
Protein denaturation → DIC, coagulopathy, embolic events

EPIDEMIOLOGY

- ~700 deaths per year[18]
- Leading cause of morbidity and mortality among U.S. high school athletes
- Early recognition and tx is priority

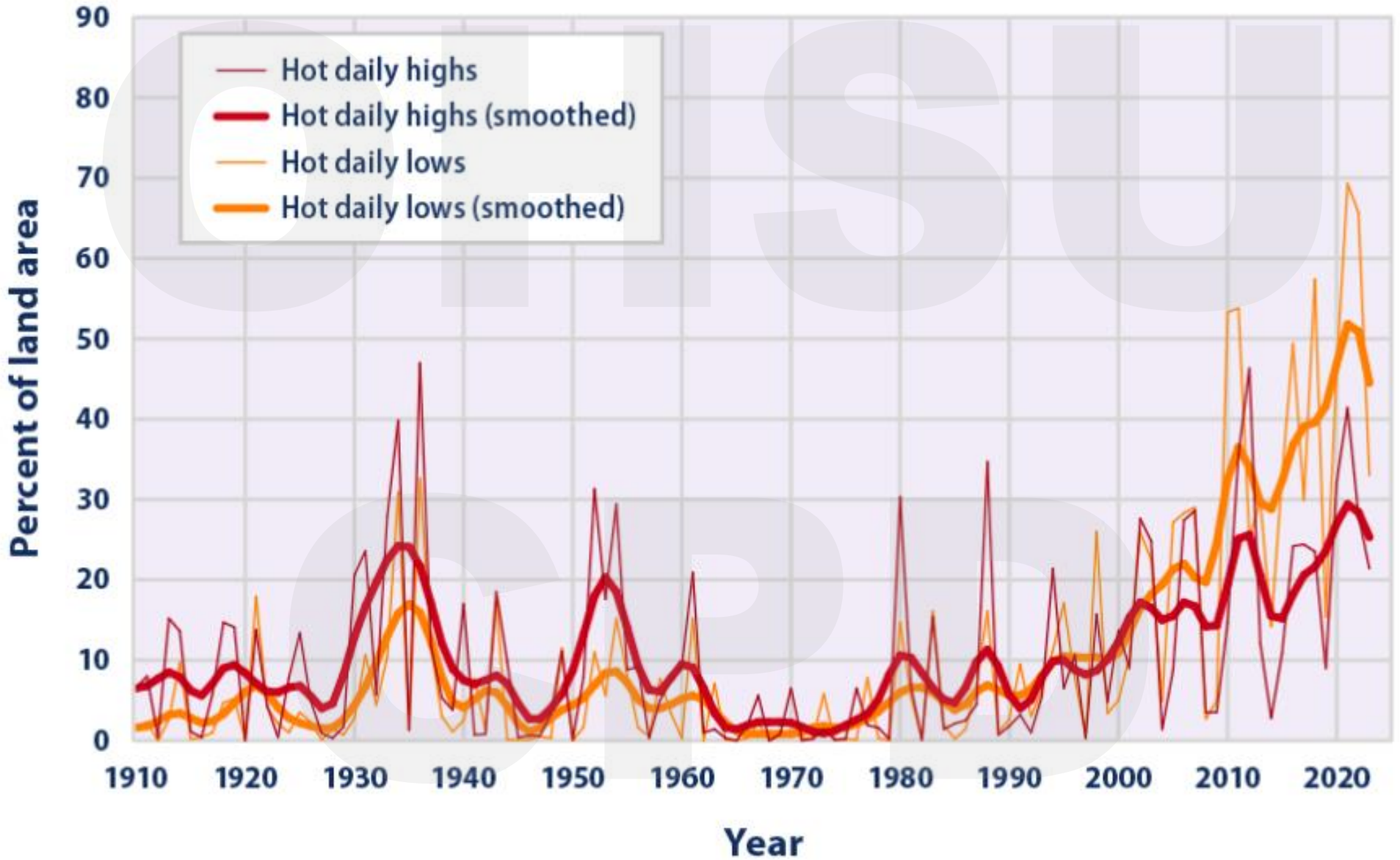
Photo sources: denverhealth.org, dreamstime.com

Figure 1. Deaths Classified as "Heat-Related" in the United States, 1979–2022



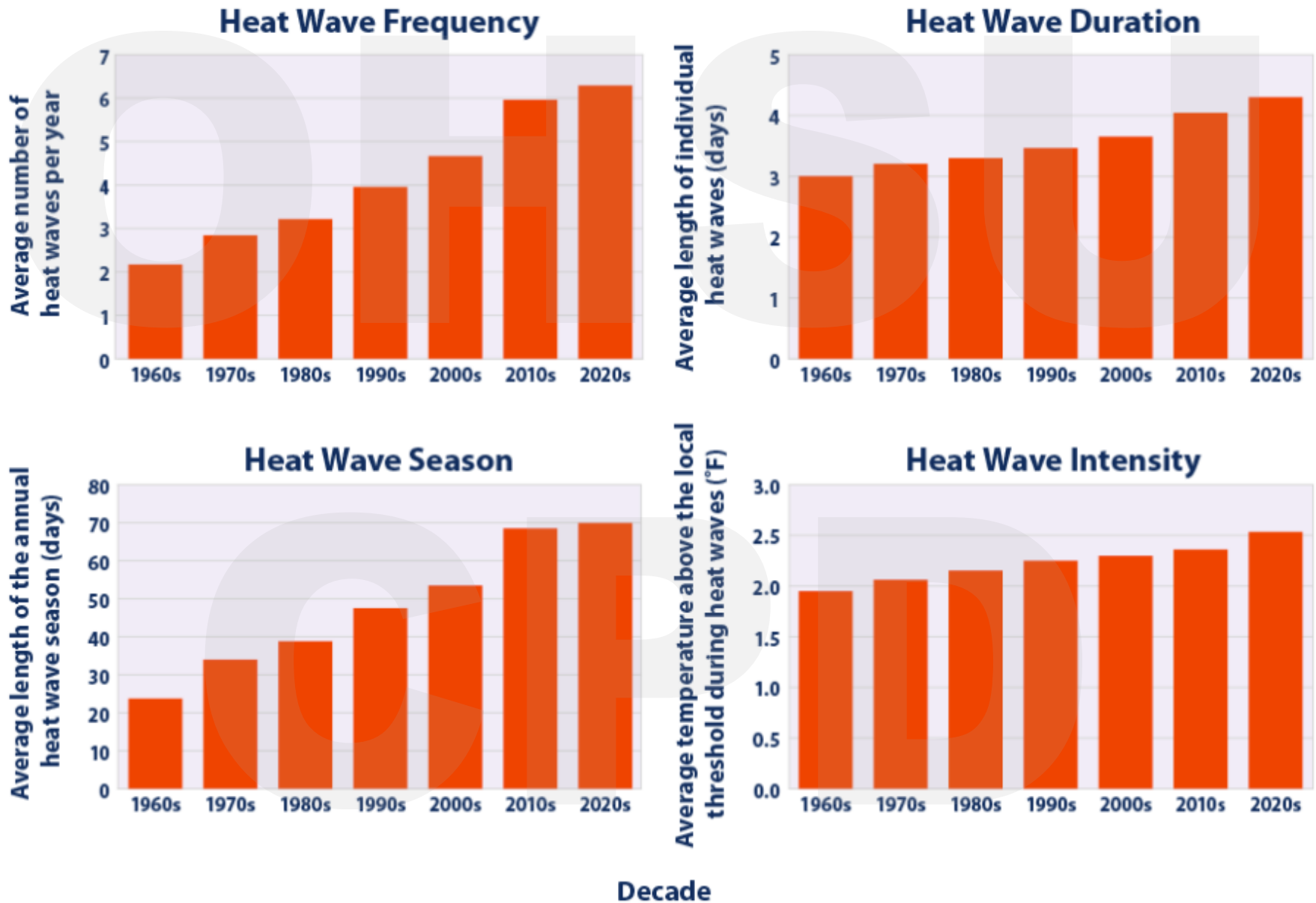
Data Source: CDC

Figure 1. Area of the Contiguous 48 States with Unusually Hot Summer Temperatures, 1910–2023

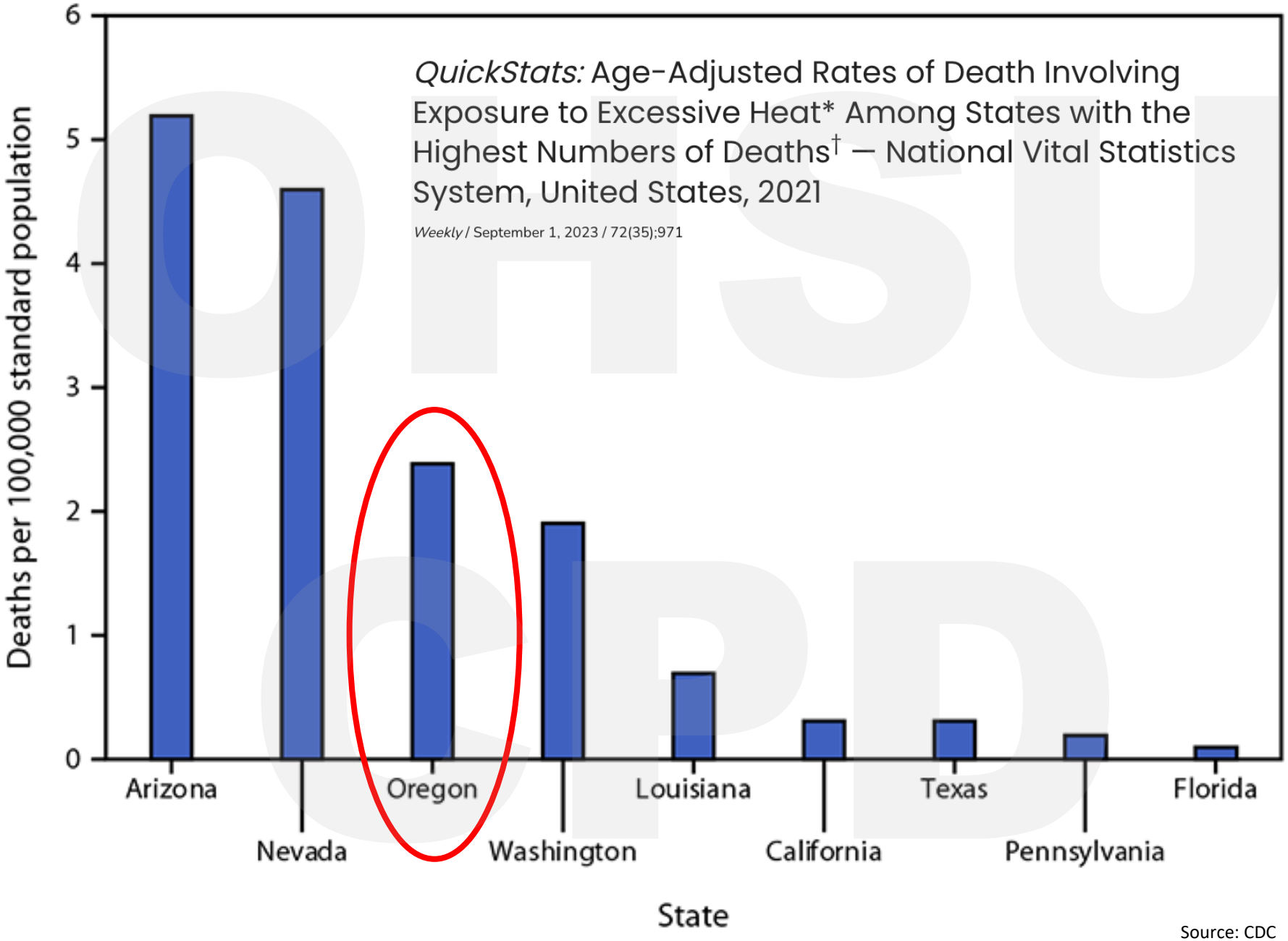


Data Source: NOAA 2024

Figure 1. Heat Wave Characteristics in the United States by Decade, 1961–2023

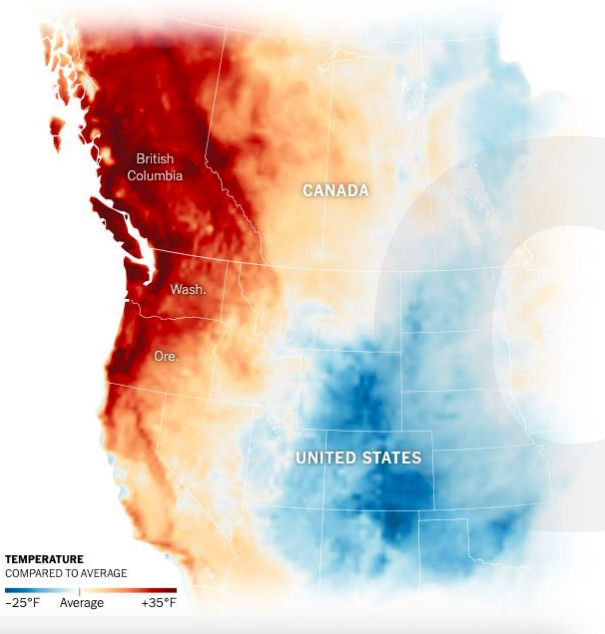


Data Source: NOAA 2024

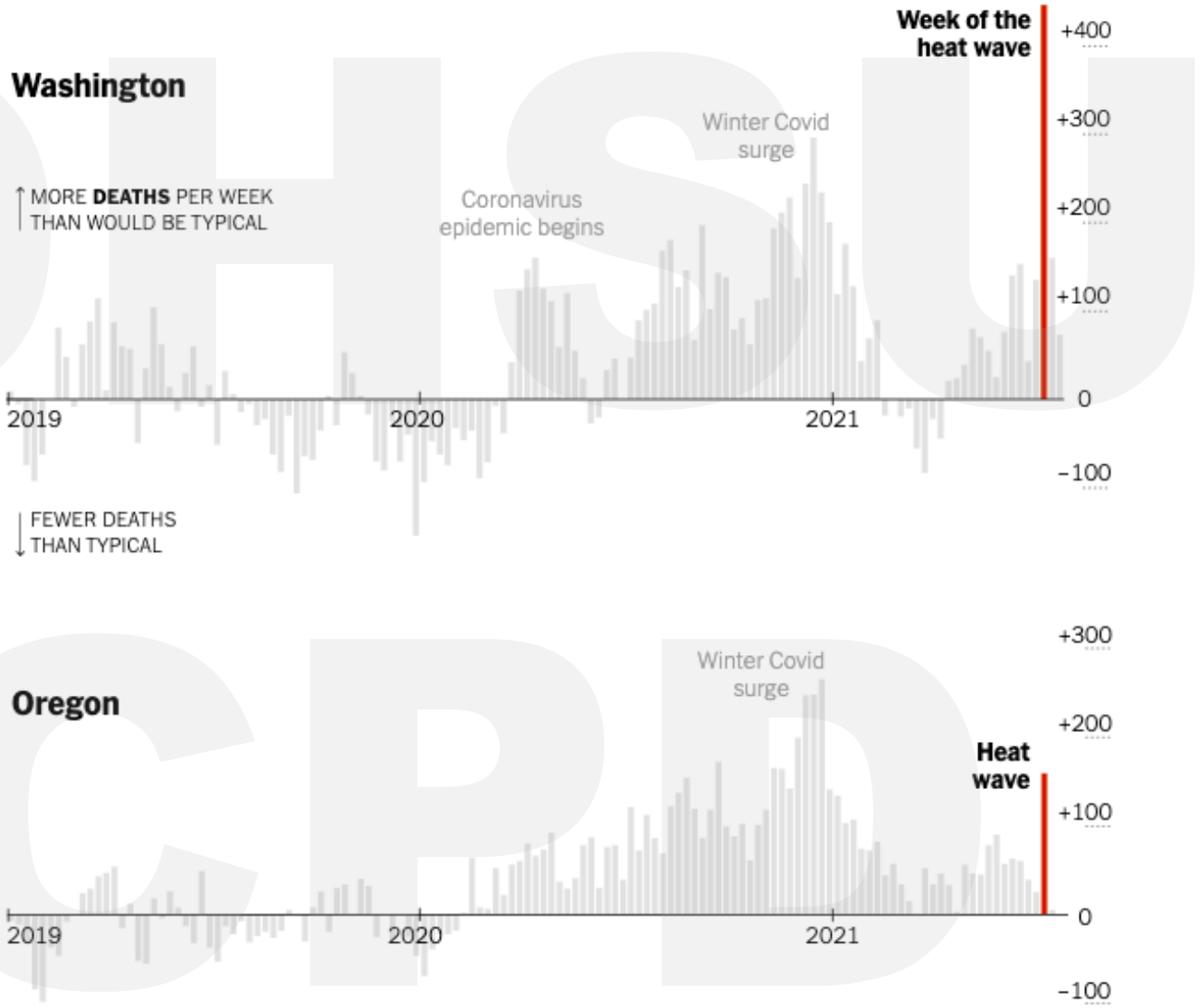

QuickStats: Age-Adjusted Rates of Death Involving Exposure to Excessive Heat* Among States with the Highest Numbers of Deaths† — National Vital Statistics System, United States, 2021
Weekly / September 1, 2023 / 72(35);971
Deaths per 100,000 standard population
6
5
4
3
2
1
0
Arizona
Nevada
Oregon
Washington
Louisiana
California
Texas
Pennsylvania
Florida
State

Source: CDC

The Late June Heat Wave

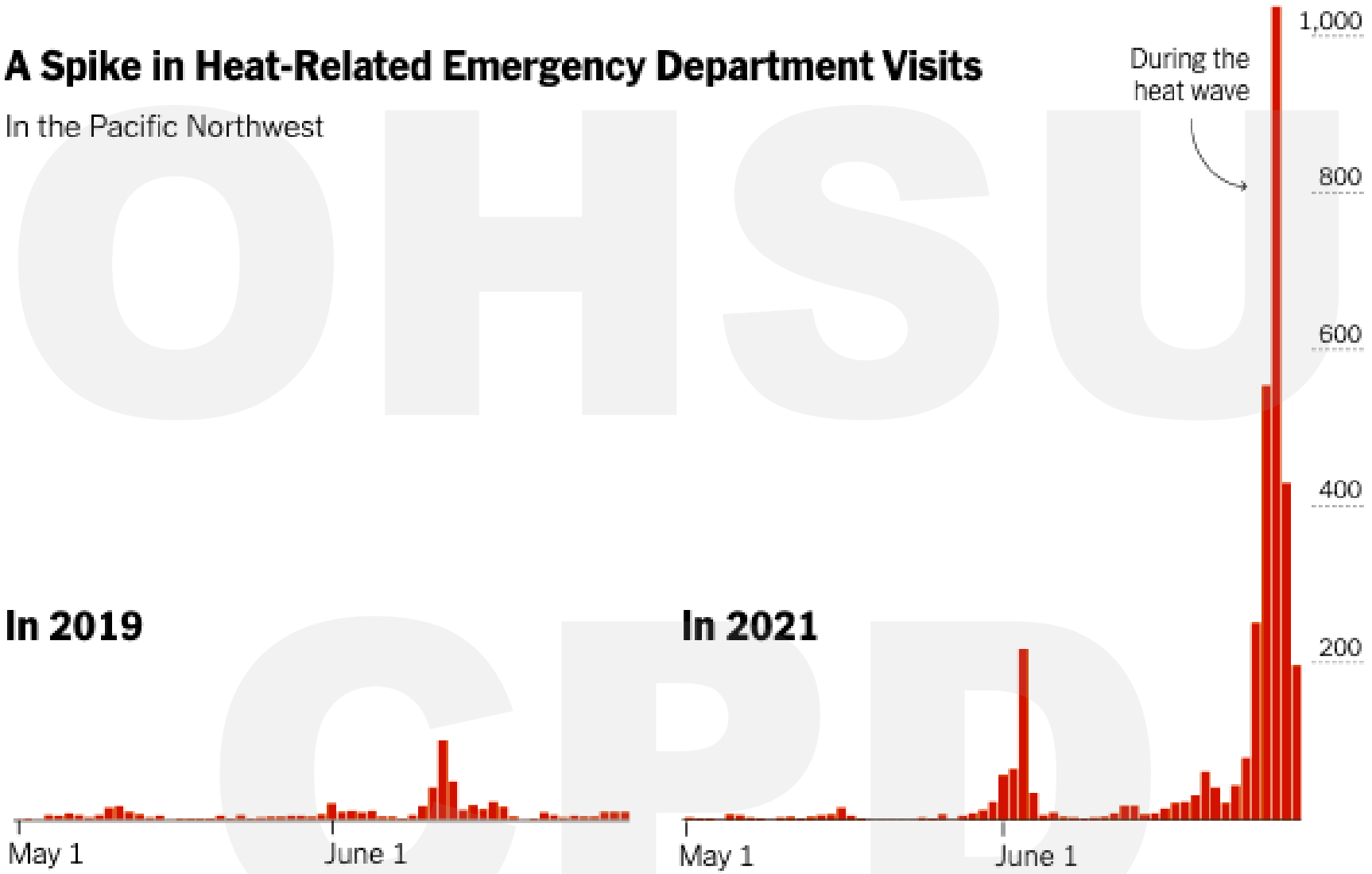


The New York Times



Source: Centers for Disease Control and Prevention • Deaths in recent weeks are most likely undercounted because of lags in reporting.

Source: https://www.nytimes.com/interactive/2021/08/11/climate/deaths-pacific-northwest-heat-wave.html

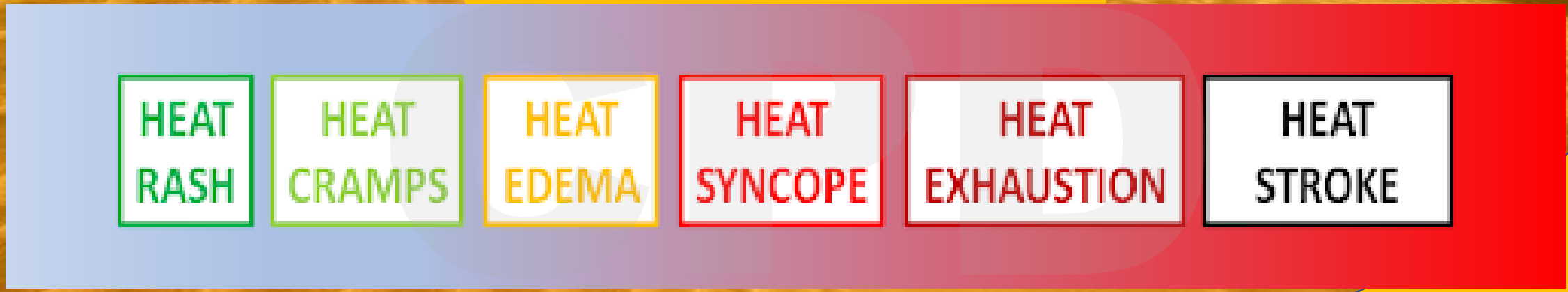


Source: https://www.nytimes.com/interactive/2021/08/11/climate/deaths-pacific-northwest-heat-wave.html

HEAT INJURY

Hyperthermia: elevated body temperature due to failed thermoregulation that occurs when a body produces or absorbs more heat than it dissipates

Spectrum of Severity



Source: http://sportmedschool.com/heat-related-illness/

HEAT RASH

- **Clinical Features**
  - Maculopapular rash or fluid filled raised bumps
  - Presents underneath clothed areas where fabric rubs

- **Management**
  - Cool skin
  - Avoid further heat exposure
  - Consider steroid cream

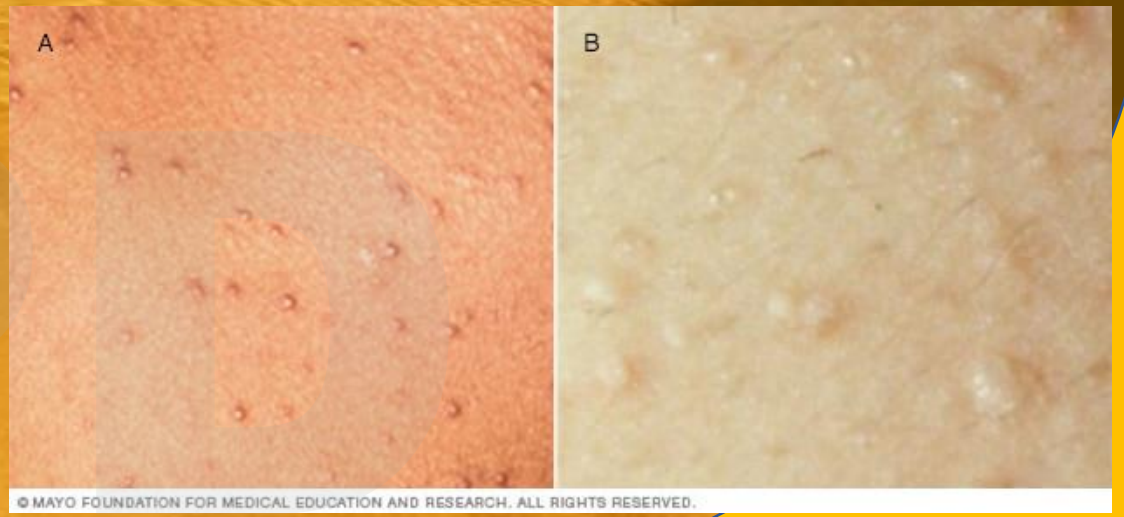


Photo Source: osfhealthcare.org, Mayo Foundation

HEAT CRAMPS

- **Clinical Features**
  - Localized, painful, involuntary spasms of large skeletal muscles

- **Management**
  - Rest
  - Cool down
  - Oral salt solutions or electrolyte replacement
  - Passive stretching

Photo Source: HippoEM

HEAT EDEMA

- **Clinical Features**
  - Benign, self-limiting
  - Accumulation of interstitial fluid

- **Management**
  - Extremity elevation
  - Compression stockings
  - Avoid high temperatures
  - Diuretics ineffective

Photo Source: https://www.centerforvein.com/

HEAT SYNCOPE

- **Clinical Features**
  - Transient loss of consciousness
  - Relatively rapid return to normal function

- **Management**
  - Rule out other medical causes
  - Remove from heat
  - Passive cooling
  - Isotonic or hypertonic oral fluids
  - Flex leg muscles

Photo Source: HippEM

HEAT EXHAUSTION

- **Clinical Features**
  - Headache, weakness, fatigue, thirst, nausea, dizziness, muscle aches

- **Management**
  - Remove from heat
  - Oral isotonic or hypertonic fluids
  - If more severe → IV fluid (isotonic), conductive/convective cooling

Photo Source: medicalnewstoday.com

HEAT STROKE

- High mortality!
- Core temp above 40°C (104°F) with **nervous system dysfunction**
- Loss of temperature regulation

Photo Source: survivalstronghold.com

HEAT STROKE

Classic

Source: metro.co.uk

Exertional

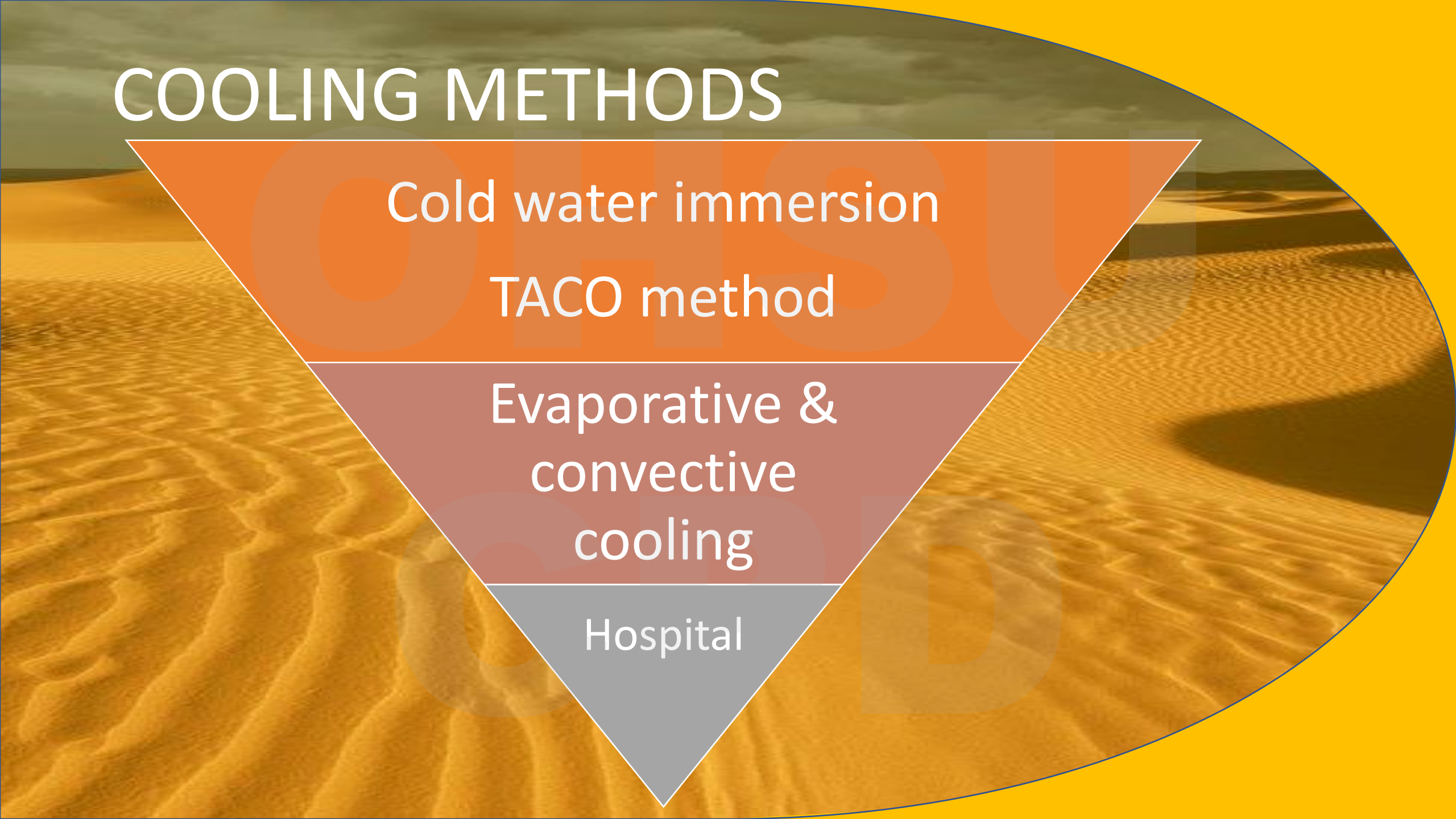
Source: https://www.siumed.edu/

HEAT STROKE

- **Field Management**
  - Remove from heat source
  - Support ABCs
  - Active cooling
  - IV fluids
  - Evacuation

- **Hospital Management**
  - Foley temperature probe
  - Continue active cooling
  - Remove at 39°C (102°F)
  - Cold IV fluids
  - Antipyretics ineffective

COOLING METHODS



PREVENTION

Acclimatization

- Successive exposures to heat over a week can lower physiologic strain by up to 20%[13]

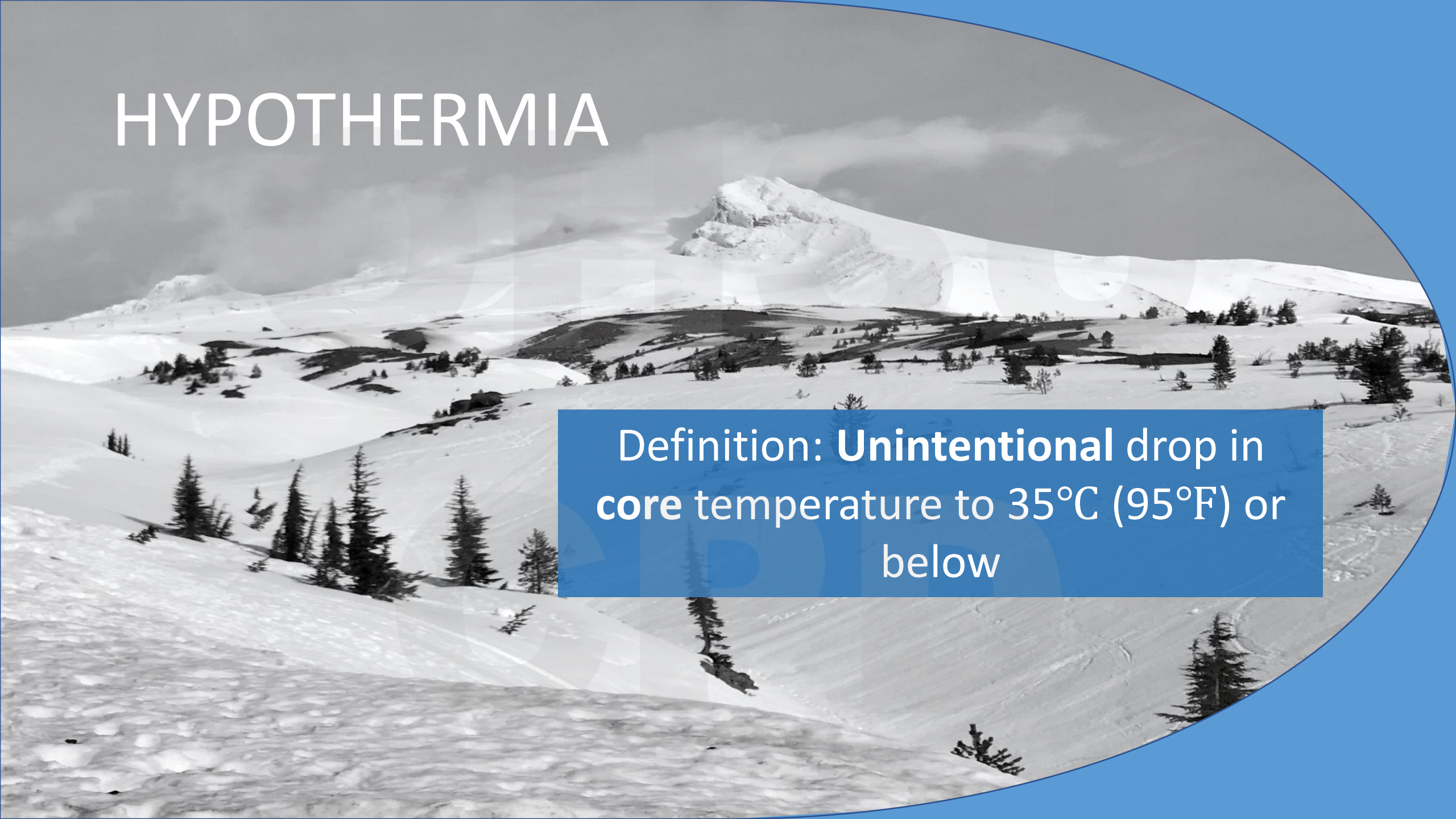
Hydration

- As little as a 2-3% decrease in body weight due to fluid losses correlates with elevated core temperatures during exertion in heat[13]

Environmental

- Wet-bulb globe temperature (WBGT) index
  - Temperature, humidity, solar radiation
- Heat index

HYPOTHERMIA



Definition: **Unintentional** drop in **core** temperature to 35℃ (95℉) or below

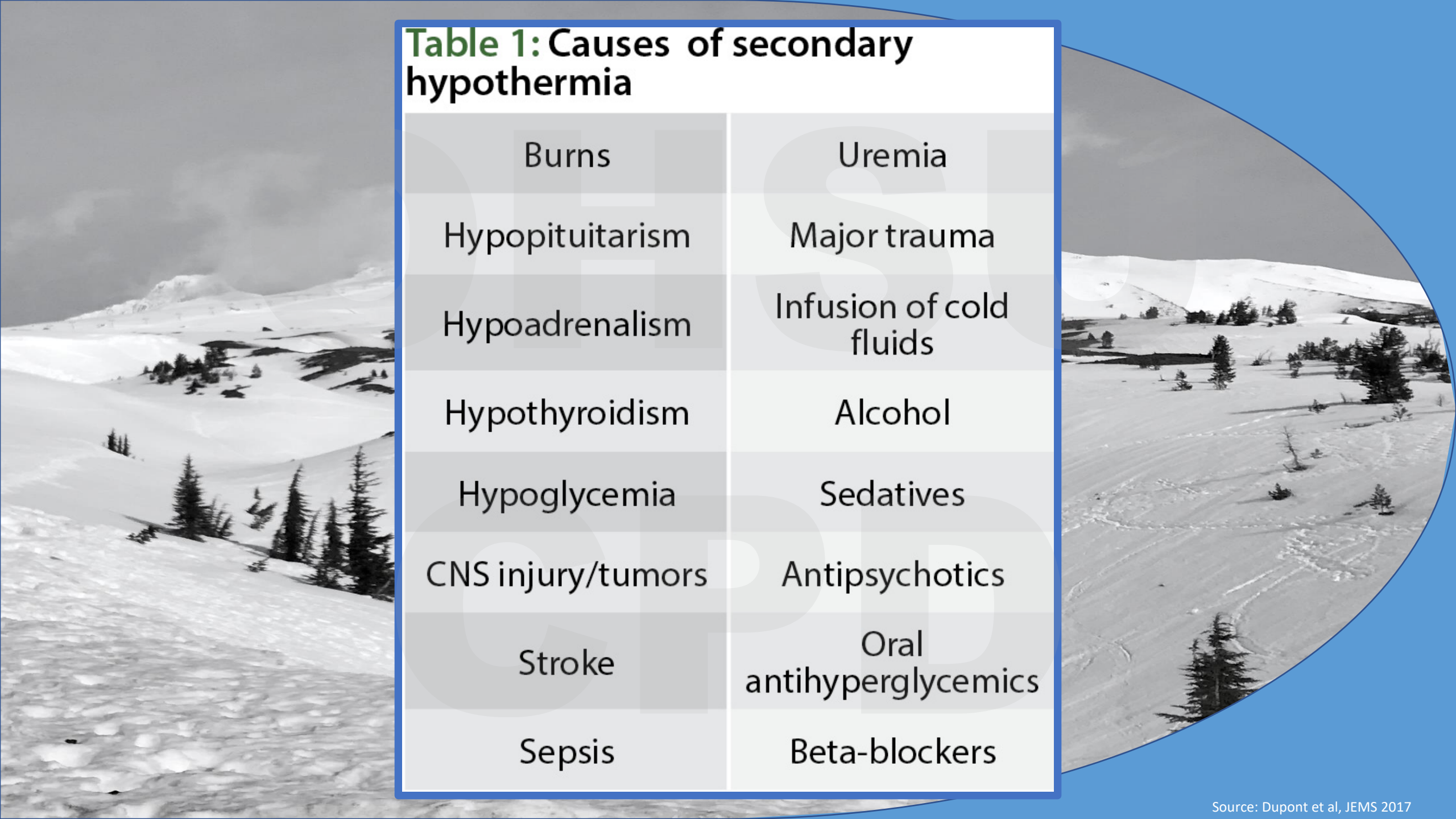


Table 1: Causes of secondary hypothermia

Burns	Uremia
Hypopituitarism	Major trauma
Hypoadrenalism	Infusion of cold fluids
Hypothyroidism	Alcohol
Hypoglycemia	Sedatives
CNS injury/tumors	Antipsychotics
Stroke	Oral antihyperglycemics
Sepsis	Beta-blockers

Source: Dupont et al, JEMS 2017

CLASSIFICATION

Standard	Swiss	Temperature	Symptoms
Cold Stress	--	35 - 37°C (95 - 98°F)	+Shivering Able to care for oneself
Mild	HT I	32 - 35°C (90-95°F)	+Shivering Normal mental status Difficulty caring for oneself
Moderate	HT II	28 - 32°C (82-90°F)	Altered mental status Usually no shivering Need external rewarming
Severe	HT III	24 - 28°C (75-82°F)	Unconscious High risk of cardiac dysrhythmias or cardiac arrest
Profound	HT IV HT V	< 24 °C (75°F)	Unconscious Vital signs usually absent – apparent death Death due to irreversible hypothermia: < 13.7°C

CLINICAL MANIFESTATIONS

Brain activity decreases (33-34°C) → Irritability, confusion, poor memory, slurred speech, apathy, poor decision-making, lethargy, somnolence, coma

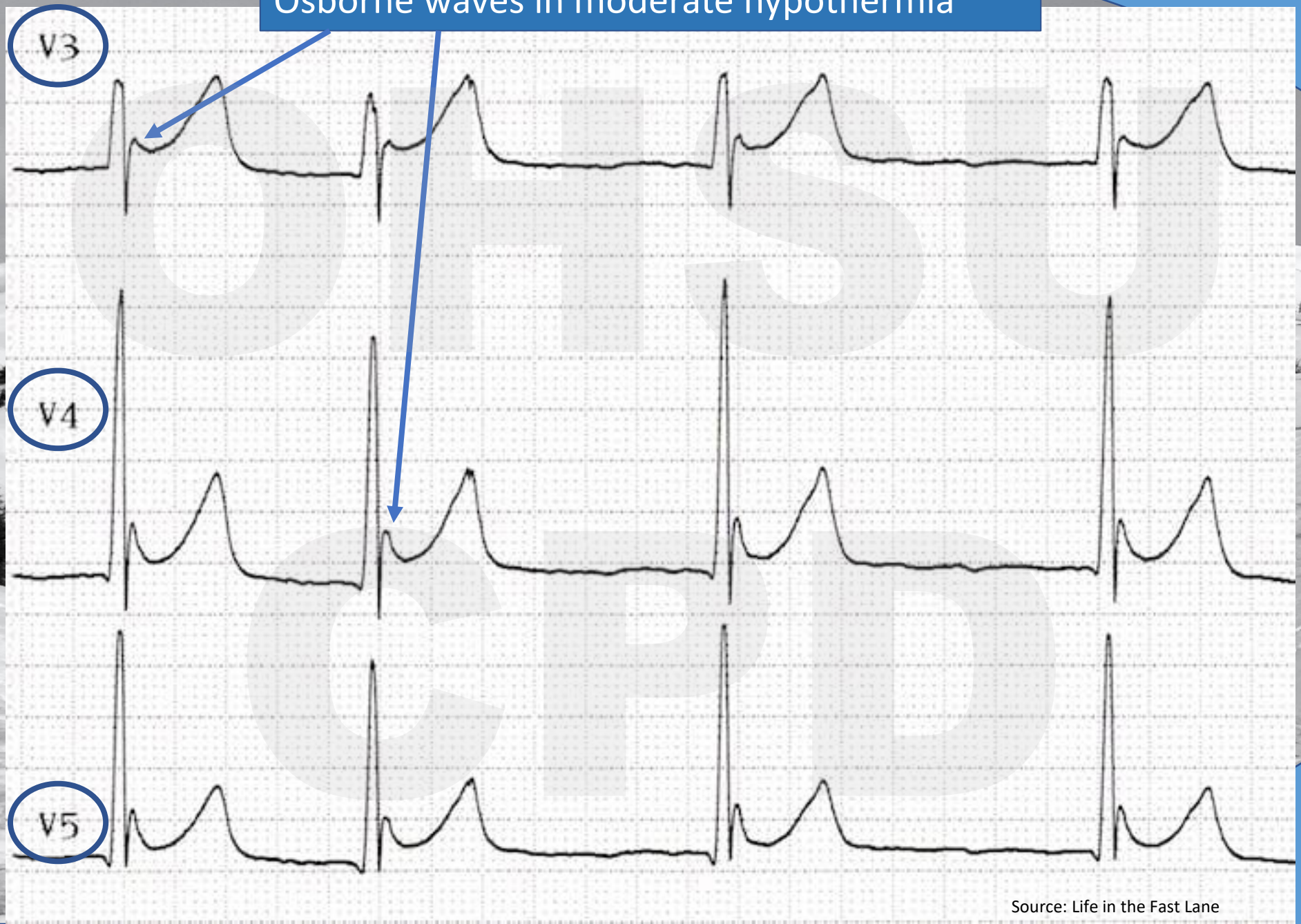
Bradycardia (below 30°C) → reduced cardiac output
Dysrhythmias

Decreased ventilatory response to CO_2 → hypoventilation and respiratory acidosis

Cold-induced diuresis → reduced circulating blood volume

Coagulopathy and hemoconcentration

Osborne waves in moderate hypothermia



Source: Life in the Fast Lane

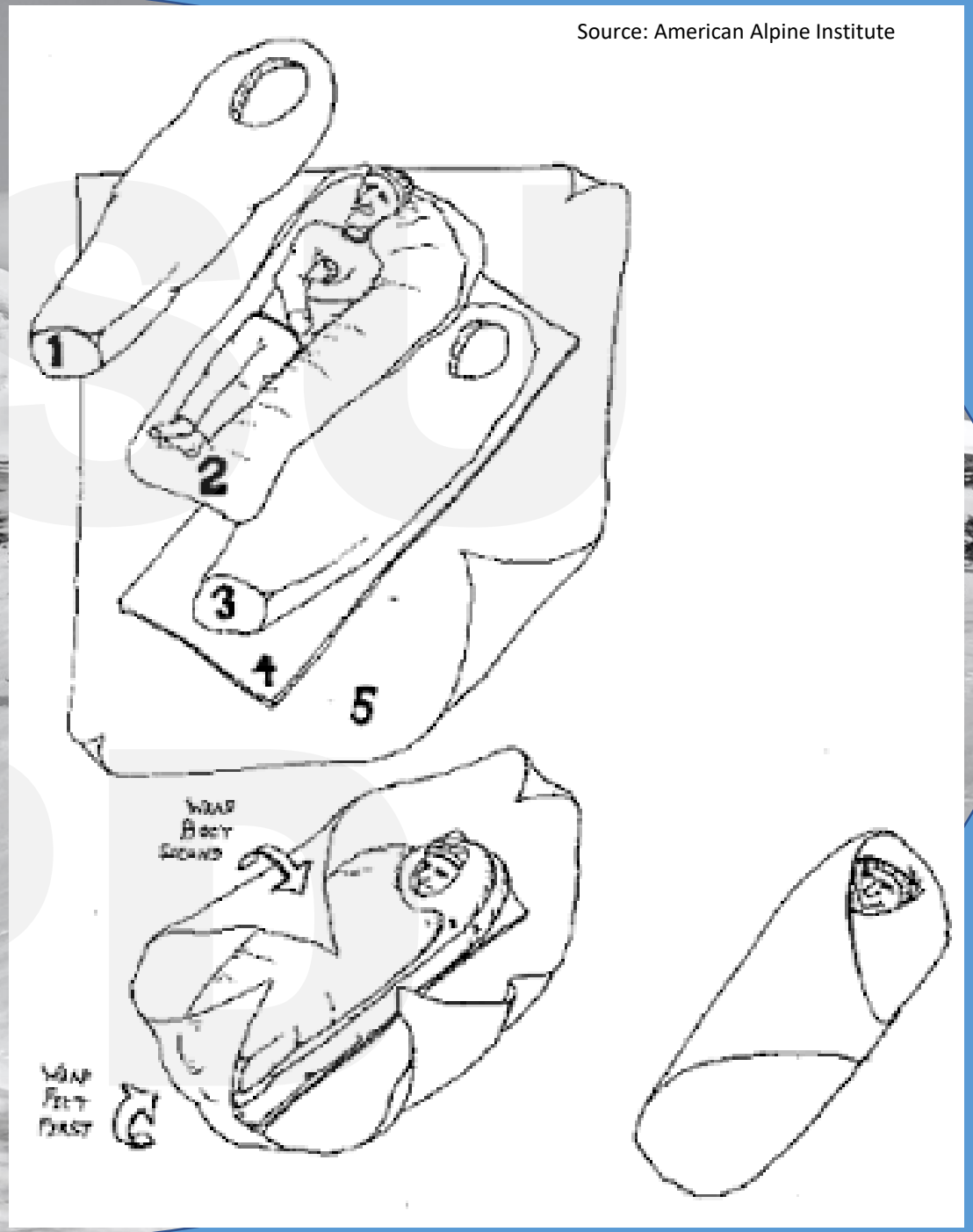
MANAGEMENT

- **Mild Hypothermia**
  - Protect from further cooling
  - Seek shelter
  - Passive warming
  - Rest for at least 30 min

Photo Source: https://www.pinterest.com/pin/525443481497961339/

MANAGEMENT

- **Moderate Hypothermia**
  - Active external rewarming
  - Hypowrap
  - Warm IV fluids
  - IV or IO glucose
  - Handle gently and reassess often
  - No standing or walking

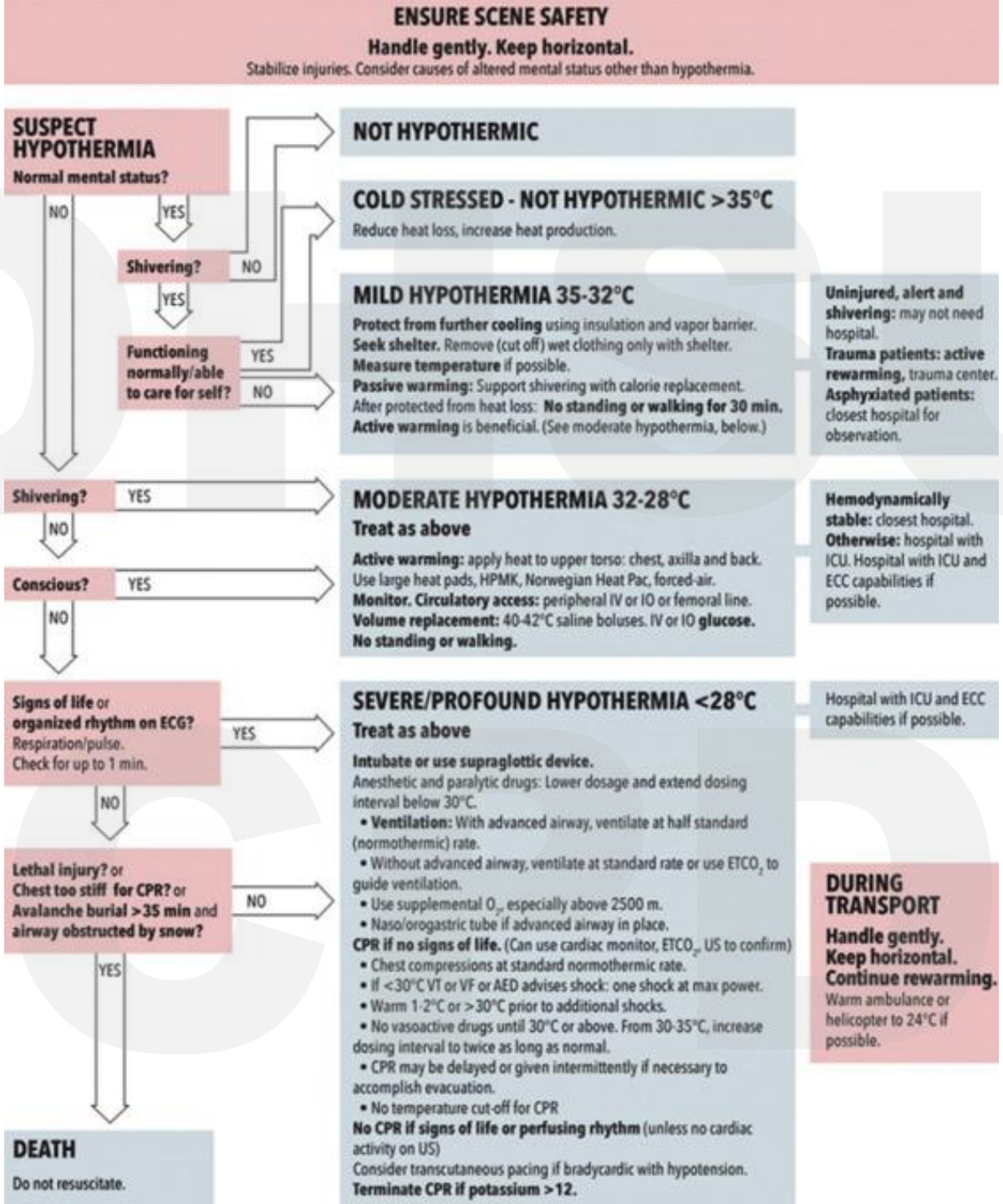


MANAGEMENT

- **Severe Hypothermia**
  - Handle gently and keep horizontal
  - ABCs
    - CPR considerations
  - Utility of rescue
  - Active rewarming to core
  - Transport carefully

Photo Source: LiveScience.com

WMS Practice Guidelines 2019



Source: Dow et al, Wild Environ Med, 2019

ASSESS COLD PATIENT

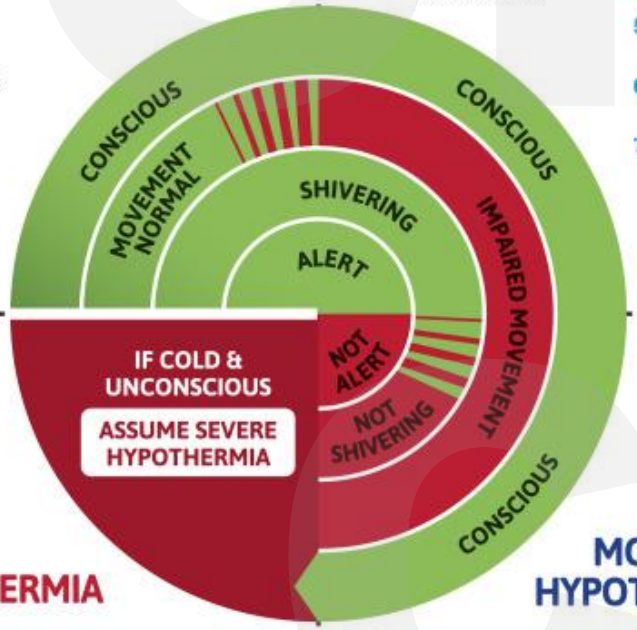
1. From outside ring to centre: assess Consciousness, Movement, Shivering, Alertness
2. Assess whether normal, impaired or no function
3. The colder the patient is, the slower you can go, once patient is secured
4. Treat all traumatized cold patients with active warming to upper trunk
5. Avoid burns: following product guidelines for heat sources; check for excessive skin redness

COLD STRESSED, NOT HYPOTHERMIC

1. Reduce heat loss *(e.g., add dry clothing)*
2. Provide high-calorie food or drink
3. Move around/ exercise to warm up

MILD HYPOTHERMIA

1. Handle gently
2. Have patient sit or lie down for at least 30 min.
3. Insulate/ vapour barrier
4. Give heat to upper trunk
5. Give high-calorie food/drink
6. Monitor for at least 30 min.
7. Evacuate if no improvement



SEVERE HYPOTHERMIA

1. Treat as Moderate Hypothermia, and
   - *a) IF* no obvious vital signs, *THEN* 60-second breathing / pulse check, or assess cardiac function with cardiac monitor
   - *b) IF* no breathing / pulse, *THEN* Start CPR
2. Evacuate carefully ASAP

MODERATE HYPOTHERMIA

1. Handle gently
2. Keep horizontal
3. No standing/walking
4. No drink or food
5. Insulate/ vapour barrier
6. Give heat to upper trunk
7. Volume replacement with warm intravenous fluid (40-42°C)
8. Evacuate carefully

Funded by the Government of Canada | Canada

BICOrescue.com

Baby It's COLD OUTSIDE

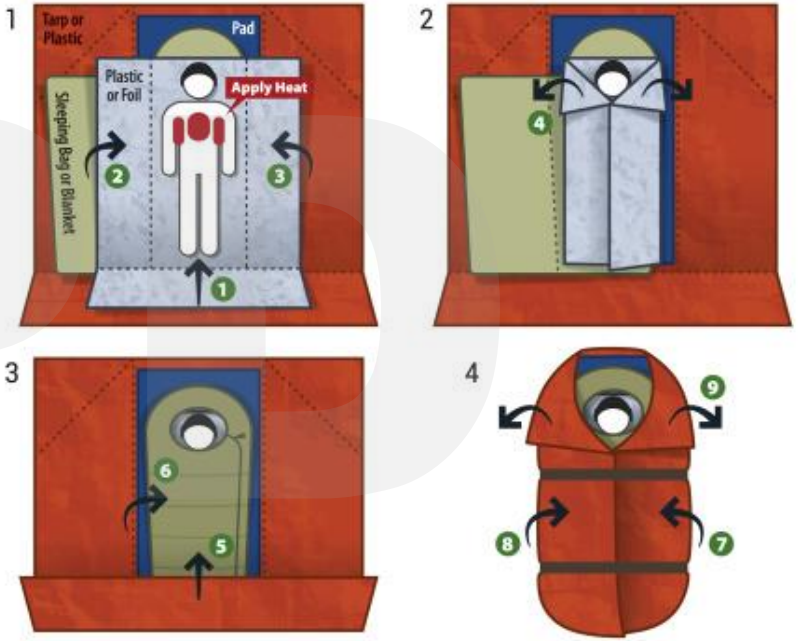
CARE FOR COLD PATIENT

SUGGESTED SUPPLIES FOR SEARCH/RESPONSE TEAMS IN COLD ENVIRONMENTS:

- 1 - Tarp or plastic sheet for vapour barrier outside sleeping bag
- 1 - Insulated ground pad
- 1 - Hooded sleeping bag (or equivalent)
- 1 - Plastic or foil sheet (2 x 3 m) for vapour barrier placed inside sleeping bag
- 1 - Source of heat ***for each team member*** *(e.g., chemical heating pads, or warm water in a bottle or hydration bladder)*, or ***each team*** *(e.g., charcoal heater, chemical / electrical heating blanket, or military style Hypothermia Prevention and Management Kit [HPMK])*

INSTRUCTIONS FOR HYPOTHERMIA WRAP "The Burrito"

1. *Dry or damp clothing:* *Leave clothing on*
2. *Very wet clothing:*
   - ***IF*** Shelter / Transport is ***less than*** 30 minutes away, ***THEN*** *Wrap immediately*
   - ***IF*** Shelter / Transport is ***more than*** 30 minutes away, ***THEN*** *Protect patient from environment, remove wet clothing and wrap*
3. *Avoid burns: follow product instructions; place thin material between heat and skin; check hourly for excess redness*



Source: Zafran et al. Wild Environ Med. 2014

COMPLICATIONS

- **Afterdrop**
  - Cold blood from extremities goes to core
  - Worsens effects of hypothermia on heart and brain
  - Affected by method of rewarming

Photo Source: https://openwaterswimming.com/

COLD WATER IMMERSION

- **Physiologic Responses**
  - Cold shock
  - Cold incapacitation
  - Hypothermia
  - Peri-rescue collapse
    - Sudden vasodilation → loss of hydrostatic pressure → decreased CO
    - Afterdrop can worsen

Photo Source: https://openwaterswimming.com/

FREEZING INJURIES

FrostNIP

- Superficial **nonfreezing** cold injury
- Intense vasoconstriction
- Numbness and pallor resolve after warming

FrostBITE

- Freezing of tissue
- 1st - 4th degree based on depth of tissue affected

Photo source: Auerbach's Wilderness Medicine, 7th ed. 2017

FROSTBITE

Field Management

- Avoid refreezing!
- Keep hydrated
- Analgesia (ibuprofen)
- Remove jewelry
- Elevate extremity
- Consider active rewarming
- Topical aloe vera
- Dry bulky dressings

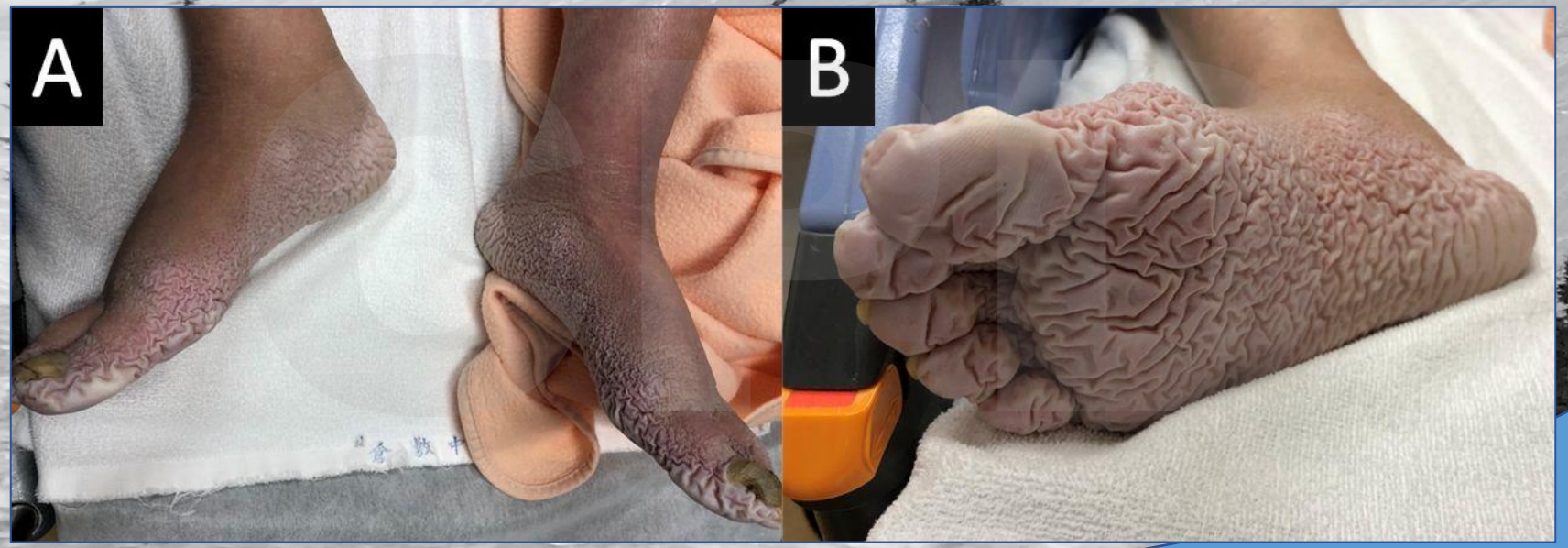
Hospital Management

- Tetanus ppx
- Rewarm in warm water bath
  - 98.6-102.2°F (37-39°C)
- Iloprost – FDA approved

TRENCH FOOT (IMMERSION FOOT)

- **Clinical Features**
  - Tingling, itching, prickliness
  - Pain, swelling, numbness
  - Cold and blotchy skin
  - Blisters may form

- **Management**
  - Apply warm packs or soaking in warm water for approximately 5 min



Source: postgraduate medical journal, BMP

PERNIO (CHILBLAINS)

- **Clinical Features**
  - Localized, inflammatory, bluish-red lesions

Source: Wikipedia

- **Management**
  - Dry
  - Gentle massage
  - Avoid active rewarming above 30°C (86°F)
  - Topical steroid if sores
  - Nifedipine if severe

COLD URTICARIA

- **Clinical Features**
  - Localized or generalized wheals, redness, swelling, itching

Source: Auerbach's Wilderness Medicine 7th ed, 2017

- **Management**
  - Antihistamines
  - Corticosteroids, epi if severe

PREVENTION IS KEY

- Avoid dehydration
- Acclimatization
- Proper clothing
- Fitness level

Source: everydayhealth.com

REFERENCES

1) Baumgartner EA, Belson M, Rubin C, et al. Hypothermia and other cold-related morbidity emergency department visits: United States, 1995-2004. *Wilderness Environ Med.* 2008;19(4):233-237.

2) Bessen H, Ngo B: Hypothermia. In Tintinalli J, Stapczynski JS, Ma OJ, et al. (Eds.), *Tintinalli's emergency medicine: A comprehensive study guide.* McGraw-Hill Education: New York, 2016.

3) Callaway CW, Donnino MW, Fink EL, et al. Part 8: Post-cardiac arrest care: 2015 American Heart Association guidelines update for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation.* 2015;132(18 Suppl 2):S465-S482.

4) CDC, C. f. (2010). Centers for Disease Control: Heat Illness among high school athletes – United States, 2005 – 2009. Atlanta, Georgia, USA: Morbidity and Mortality Weekly Report – CDC.

5) Charkoudian N and Crawhaw L. Thermoregulation. In Auerbach P (Ed.), *Wilderness medicine, 7th edition.* Mosby Elsevier: Philadelphia, pp. 120-134, 2017.

6) Danzl D, Huecker M. Accidental hypothermia. In Auerbach P (Ed.), *Wilderness medicine, 7th edition*. Mosby Elsevier: Philadelphia, pp. 135-162, 2017.

7) Dow J et al. Wilderness Medical Society Practice Guidelines for Out of Hospital Evaluation and Treatment of Accidental Hypothermia: 2019 Update. WEMJ. 2019; 30(4) S47-69.

8) Du Pont D, Dickinson E. Hypothermia. JEMS. 42(11); 2017. https://www.jems.com/2017/11/01/identifying-and-managing-accidental-hypothermia/

9) Howard J, Androne N, Alcover K. Trends of Heat-Related Deaths in the US 1999-2023. JAMA. 2024;332;(14):1203-1204.

10) Howe. (2007). Heat-Related Illness in Athletes. American Journal of Sport Medicine , 1384 -1395.

11) Leci E and Briscoe G. Heat Related Illness. Sport Med School. Feb 2020. http://sportmedschool.com/heat-related-illness/

12) Leon, B. (2015). Heat Stroke. *Comprehensive Physiology* , Vol.5 (2) 611 – 647.

13) Lipman G et al. Wilderness Medical Society Practice Guidelines for Prevention and Treatment of Heat Illness: 2019 Update. WEMJ. 2019; 30(4): S33-46

14) McIntosh S et al. Wilderness Medical Society Practice Guidelines for Prevention and Treatment of Frostbite: 2024 Update. WEMJ. 2024. Jun;35(2):183-197

15) Osilla, a. S. (2019). Physiology, Temperature Regulation. Tampa, Florida, USA : StatPearls Publishing .

16) Popovich N. Choi-Schagrin W. Hidden Toll of the Northwest Heat Wave: Hundreds of Extra Deaths: https://www.nytimes.com/interactive/2021/08/11/climate/deaths-pacific-northwest-heat-wave.html. Aug 2021.

17) Toru Hifumi, Y. K. (2018). Heat stroke. Journal of Intensive Care , 320-328.

18) Vaidyanathan A, Malilay J, Schramm P, Saha S. Heat-related deaths—United States, 2004–2018. *MMWR Morb Mortal Wkly Rep.* 2020;69(24):729.


THANK YOU
Questions?