Hypothermia!

The Terra Nova viewed from an iceberg near Scott's camp

What is hypothermia?

- Clinically, a core temperature < 35°C
  - mild (shivering, numb hands, reduced dexterity)
  - moderate (violent shivering, reduced fine motor and mental function) 35 to 32 °C
  - profound (< 32°C) unconsciousness, ↓ HR and breathing, arrhythmias (<28°C), asystole (< 20°C)

Potential for hypothermia

- Extreme environments
  - Antarctic (-129°F, coldest recorded on Earth)
  - Arctic (-60°C in Siberia)
  - Altitude (↓1°C every 100 m, -40°C on Everest)
- Winter sports / military
- Water immersion
- Stranded motorists
- The elderly
  - minimum safe indoor temperature is 70°C

Ambient cold limits

- Depends on the duration and extent of exposure
  - nude, feels cold at < 25°C
  - manual dexterity, < 12°C
  - touch sensitivity, < 8°C
  - peripheral tissues freeze around -0.5°C
- wind effect, wind chill index
- water effect, 25x greater conductivity

Wind Chill Effect

Table 11.6 Wind-Chill Factor Chart

Estimated wind speed (mph)	Actual thermometer reading (°F)											
	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60
	Equivalent temperature (°F)											
Calm	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60
5	48	37	27	16	6	-5	-15	-26	-36	-47	-57	-68
10	40	28	16	4	-9	-24	-33	-46	-58	-70	-83	-95
15	36	22	9	-5	-18	-32	-45	-58	-72	-85	-99	-112
20	32	18	4	-10	-25	-39	-53	-67	-82	-96	-110	-124
25	30	16	0	-15	-29	-44	-59	-74	-88	-104	-118	-133
30	28	13	-2	-18	-33	-48	-63	-79	-94	-109	-125	-140
35	27	11	-4	-20	-35	-51	-67	-82	-98	-113	-129	-145
40	26	10	-6	-21	-37	-53	-69	-85	-100	-116	-132	-148
	Green				Yellow			Red				
(Wind speeds >40 mph have little additional effect.)	LITTLE DANGER for properly clothed person. Maximum danger of false sense of security.				INCREASING DANGER Danger from freezing of exposed flesh.			GREAT DANGER				

Adapted from *Runner's World* (1973).

Physiological Responses

- Skin blood flow (increase insulation)
  - ↓ with cooling until 10°C
  - < 10°C, hunting reaction
- Shivering
  - ↑ heat production 5 fold
  - unique to birds and mammals
- Voluntary exercise
  - ↑ heat production 15 fold
- Non-shivering thermogenesis

Non-Shivering Thermogenesis

- Babies
  - 4% body wt is brown fat (BAT)
  - rich in mitochondria
  - UCP, uncouples fuel metabolism and energy production, ↑ heat
  - stimulated by NE via β-adrenergic receptors

NST in Adults?

- NST acct for differences in cold tolerance in adults?
  - BAT in white fat?
  - Skeletal muscle NST?
- BAT role in susceptibility to obesity?

Plants that generate heat

- Arum Maculatum (type of lily called jack in the pulpit)
  - produces heat and volatizes chemicals to produce a smell to attract flies to pollinate
  - heat as high as 45°C
- Soldanella montana (alpine snowbell)
  - generates enough heat to melt surrounding snow

Chronic Exposure

- Human responses to repeated cold exposure are "unimpressive" compared to other animals
  - little more than some habituation responses
  - for years it was debated whether humans could acclimatize to cold

Cold Habituation

- Fishermen who have cold hands all day have less skin vasoconstriction

Cold Acclimatization?

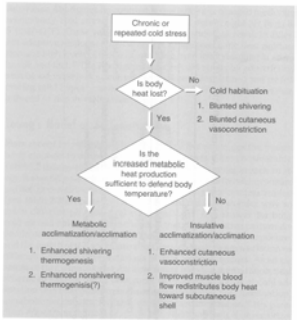
- Metabolic acclimatization
  - Increase BMR?
  - Shivering thermogenesis (3 METs)
  - Non-shivering thermogenesis
- Insulative acclimatization
  - vasoconstriction

Victor Boyarsky

Acclimation patterns (3)

- Habituation (fishermen)
  - less vasoconstriction,
  - less shivering, less increase in BMR
  - greater fall in rectal temperature
- Metabolic pattern (Ama Divers)
  - increase BMR
  - increase shivering and NST
- Insulation pattern (Australian aborigines)
  - increased VC
  - increased subcutaneous fat

What determines the acclimation pattern?



fisherman

Ama Aborigines

Ama Women Divers

- Suk Ki Hong, a lifetime of studying Ama (Japan) and hae-hyo (Korea) women divers
- Extreme cold exposures before 1977
  - frequent dives, year round, in cold water
  - deep body cooling to 35ºC
  - light cotton swim suits until 1977
- Wet suits after 1977
  - longer dives but no longer deep body cooling

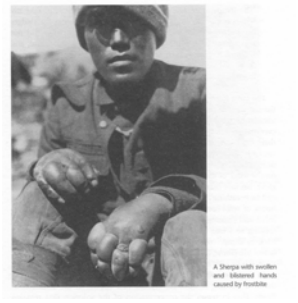
Ama Cold Acclimatization?

- Metabolic acclimatization,
  - 30% increase BMR in winter
  - increased utilization of thyroid hormone by peripheral tissues
- Insulative acclimatization
  - Increased non-fatty insulation shell
    - greater vc, better countercurrent effect, thicker muscle insulation
- Habituation acclimatization
  - lower core temperature threshold for shivering

Cold Injuries

- Chilblains
  - red, itchy patches of skin (fine capillary damage)
- pernio
  - superficial burning and pain
- Trench foot, immersion foot
  - prolonged immersion of feet in cold water
  - prolonged vc causes ischemic damage to tissues
- frost nip (surface layers), Frost bite (deeper layers),
  - freezing of the tissues

Frostbite


A Sherpa with swollen and blistered hands caused by frostbite

Unexpected effects of cold

- Increases MI, stroke, respiratory disease deaths
  - vasoconstriction
  - dehydration
  - increased blood clotting
  - longer survival of bacteria
  - closed environments
  - inhibits innate immunity

Scott vs Admundsen Story

- Roald Admundsen
  - superb skiers
  - well provisioned
  - dogsledders
- Robert Falcon Scott
  - military discipline
  - austere provisioning
  - ponies and sledges

Scott
78 days

Admundsen
57 days

Scott

- Arrived at pole to find letter from Admundsen
- 5 men with food for 4
- 800 mile return trip with sledges
- frost bite, scurvy, starvation

Admundsen

- Arrived at pole and feasted on seal meat
- only problem was a tooth ache in one member

Scott' diary

- Expedition's misfortune was not due to poor planning but to bad weather and bad luck.
- "It was no one's fault…every detail of our food supplies, clothing,and depots…worked out to perfection..We missed getting through by a narrow margin which was justifiably within the risk of such a journey".
- Scott and his remaining 2 companions died within a days walk of their next depot of food.
- Scott allowed for 4500 kcal/d/man
- Pulling sledges requires > 7000 kcal/d/man

Hypothermic emergency treatment

- 29 yr-old Norwegian woman survived accidental hypothermia and revived from a Tc of 13.7 ^{o}C
  - fell in waterfall while skiing
  - survival more likely when rapidly cooled
- immerse in warm bath
- warm air to breathe
- blood warmed with heat exchanger
- be ready for arrhythmias

Acute effects of Cold

- ↑ muscle blood flow
- ↑ cardiac output only by ↑SV
  - no ↑HR because of vc?
- ↑urine, ↓PV
- ↑EPI and NE which ↑FFA and glucose
- ↑cortisol which ↑blood glucose
- ↑thyroid hormone which ↑ met rate
- carbohydrates become the preferred fuel?

BMR and Ta

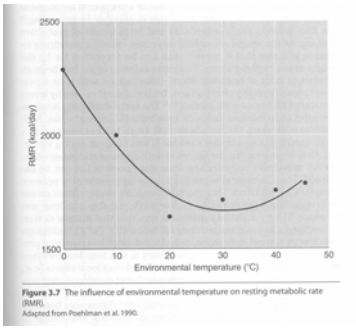


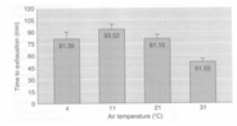
Figure 3.7 The influence of environmental temperature on resting metabolic rate (RMR).
Adapted from Poehlman et al. 1990.

Effect of cold on aerobic exercise endurance

- Increased metabolic cost
- lower body temperatures
- decreased cv endurance
  - ↓ HR max, ↓Qmax, ↓VO2max
  - less O2 delivery to muscle (Hb/O2 binding)
  - ↓ active muscle blood flow

Effect of cold on muscle function

- ↓ muscular endurance @ muscle temp < 27oC
  - reduced nerve conduction vel., ↓muscle fiber recruitment
- ↓ muscle strength and ↓ peak muscle power
  - slower force development
  - greater viscosity of sarcoplasm
  - slower chemical reactions



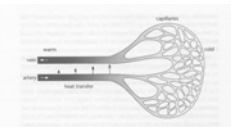
Cycling time to exhaustion

Factors that influence cold responses

- Age (children and elderly)
- Gender (females do better)
- Fitness (an advantage)
- Body fat (a big advantage)
- Alcohol (lowers blood sugar, dehydration, ↓ vd, ↓ shivering)

Other Approaches to Cold

- Countercurrent heat exchangers
  - bird legs, seal flippers, whales tails
- Specialized tissues
  - Antifreeze blood (glycoproteins), modified lipid membranes
- Estivation- body cooling and torpor under unfavorable environmental conditions



- Hibernation
  - •Metabolism 1% above BMR
- Suspended animation?

Behavior Cold Protections

- Increase metabolism
  - stamp feet
  - jump
- Increase insulation
  - clothing
- Huddling
  - birds
  - bees

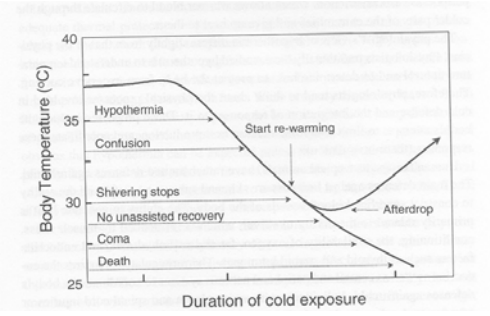
Clothing

- Clo
  - measure of clothing insulation
  - 1 clo = insulative value of a regular business suit
  - insulation nec to maintain comfort of a seated adult in a 21°C room, 50%rh, 6 m/min air flow
- COLD
  - clean, open, layers, dry

Death in Cold Water

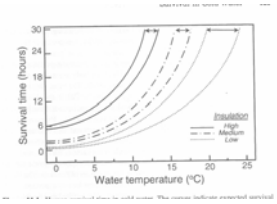
- Titanic, cause of death for most of the 1000 people not in lifeboats was hypothermia, not drowning
- Reflex gasp
- hyperventilation (muscle tetany)
- cardiac arrhythmias
- post-rescue collapse

Afterdrop



To swim or not to swim?

- **Swimming increases metabolic rate but also increases convective heat loss**
- <15-20 °C, ↓ Tc w/swim
- 16-24°C, depends on %fat
- 25-28°C, no effect of swimming on Tc
- >28°C, Tc increases with swimming



Water temp, insulation, and survival