The Ontology of Temperature

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Temperature

- We perceive temperature.
- We measure temperature.

Main Thesis

Temperature is NOT:

a social construction,
a conceptual construction,
or a purely subjective phenomenon.

Basic Oppositions

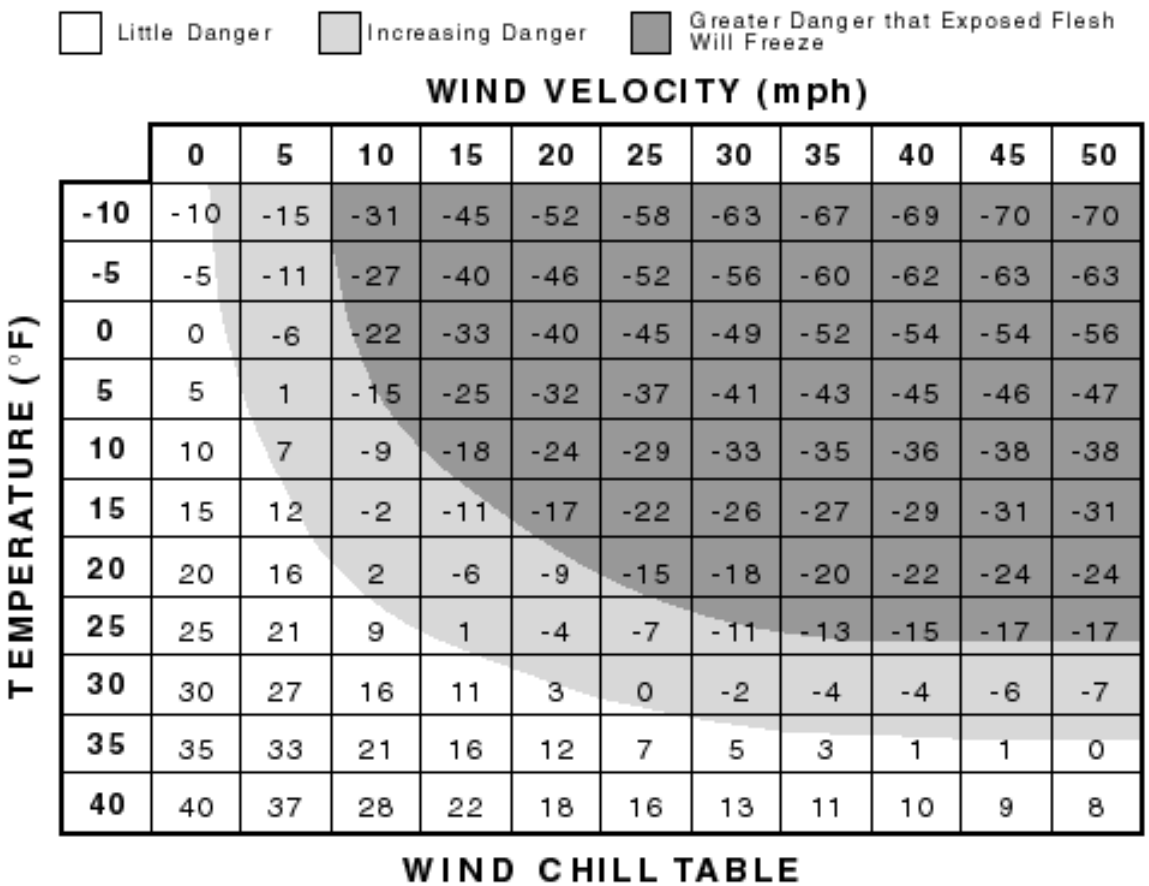
1. temperature (objective)
   versus experienced temperature (subjective)
2. temperature (as temperature)
   versus temperature as kinetic energy
3. temperature
   versus heat
4. temperature
   versus temperature scales

(1a) Objective *vs.* Subjective Macroscopic Temperature

Subjectively perceived temperature depends on:

- Objective temperature
- Wind
- Humidity
- State of health

(1b) Objective *vs.* Subjective Macroscopic Temperature



TEMPERATURE (°F) \ WIND VELOCITY (mph)	0	5	10	15	20	25	30	35	40	45	50
-10	-10	-15	-31	-45	-52	-58	-63	-67	-69	-70	-70
-5	-5	-11	-27	-40	-46	-52	-56	-60	-62	-63	-63
0	0	-6	-22	-33	-40	-45	-49	-52	-54	-54	-56
5	5	1	-15	-25	-32	-37	-41	-43	-45	-46	-47
10	10	7	-9	-18	-24	-29	-33	-35	-36	-38	-38
15	15	12	-2	-11	-17	-22	-26	-27	-29	-31	-31
20	20	16	2	-6	-9	-15	-18	-20	-22	-24	-24
25	25	21	9	1	-4	-7	-11	-13	-15	-17	-17
30	30	27	16	11	3	0	-2	-4	-4	-6	-7
35	35	33	21	16	12	7	5	3	1	1	0
40	40	37	28	22	18	16	13	11	10	9	8

(1c) Objective *vs.* Subjective Macroscopic Temperature

Laws of Classical Thermodynamics

0. If two systems are separately in thermal equilibrium with a third, then they must also be in thermal equilibrium with each other.
1. The principle of energy conservation covers also thermal energy.
2. No cyclic machine can convert thermal energy wholly into other forms of energy.

(2a) Temperature *vs.* Kinetic Energy

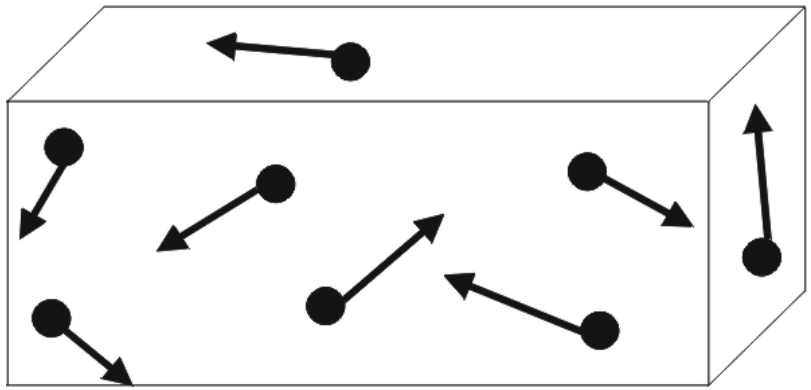
- Temperature (T) is **proportional** to average internal kinetic energy (E_a):

$$3kT/2 = E_a.$$

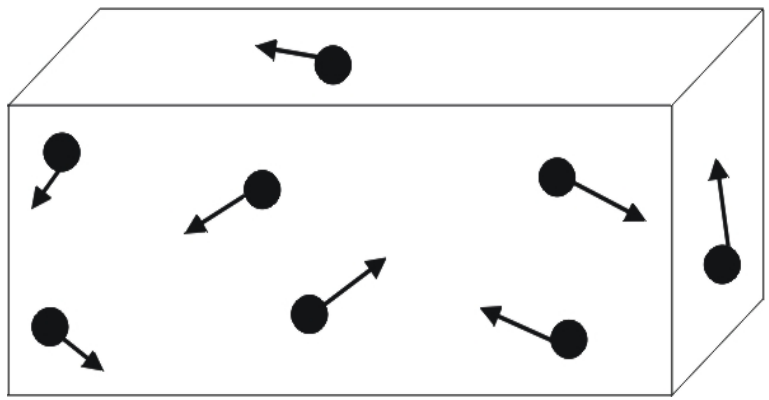
- In gases, it is energy of moving molecules; in solids, it is energy of vibrating atoms.
- Non-reductionism:
  Temperature is **not identical** with kinetic energy (Karl Popper).

(2b) Temperature *vs.* Kinetic Energy

- High temperature



- Low temperature



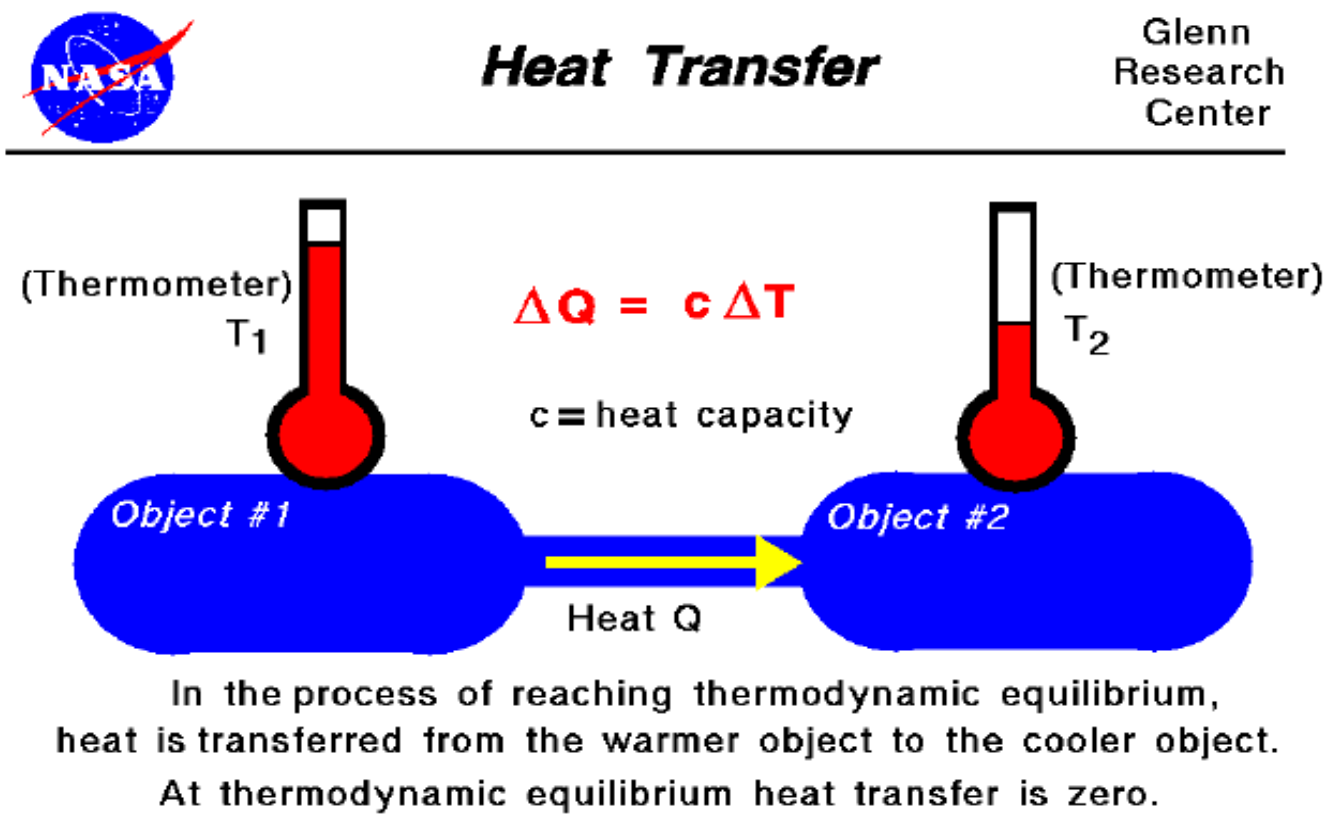
(2c) Temperature *vs.* Kinetic Energy

- Temperature is proportional to **average** and **internal** kinetic energy of an aggregate.
- A single moving molecule has no average kinetic energy.
- A single moving molecule has no internal kinetic energy.
- An average is not a real quality or property.

(2d) Temperature *vs.* Kinetic Energy

- Temperature **supervenes** on aggregates with internal kinetic energy.
- (a) Without internal kinetic energy no temperature.
- (b) Same average internal kinetic energy, same temperature.
- (c) Temperature can be multiply realized (in aggregates of moving molecules and in aggregates of vibrating atoms).

(3a) Temperature *vs.* Heat



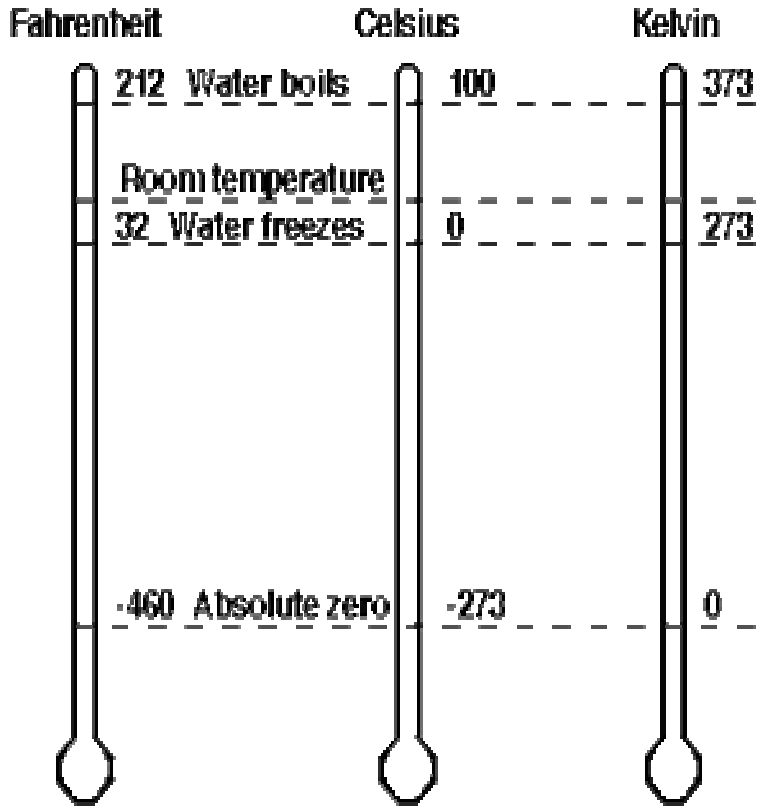
(3b) Temperature *vs.* Heat

- Qualities and properties cannot be transferred, only matter, stuff, and substances can.
- There is no heat *substance* (“caloric”).
- Heat is heat *transfer*; such transfer is transfer of energy (kinetic or potential).
- The heat *capacity* of a substance is the energy required to raise the temperature of the substance one degree.

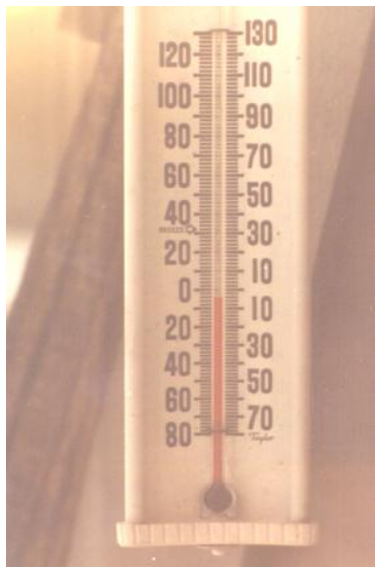
(4a) Temperature Scales

- There are several temperature scales: Celsius, Fahrenheit, Kelvin, (Réamur and Rankine).

- $^{o}F = 1.8\ ^{o}C + 32$
- $^{o}K = ^{o}C + 273$

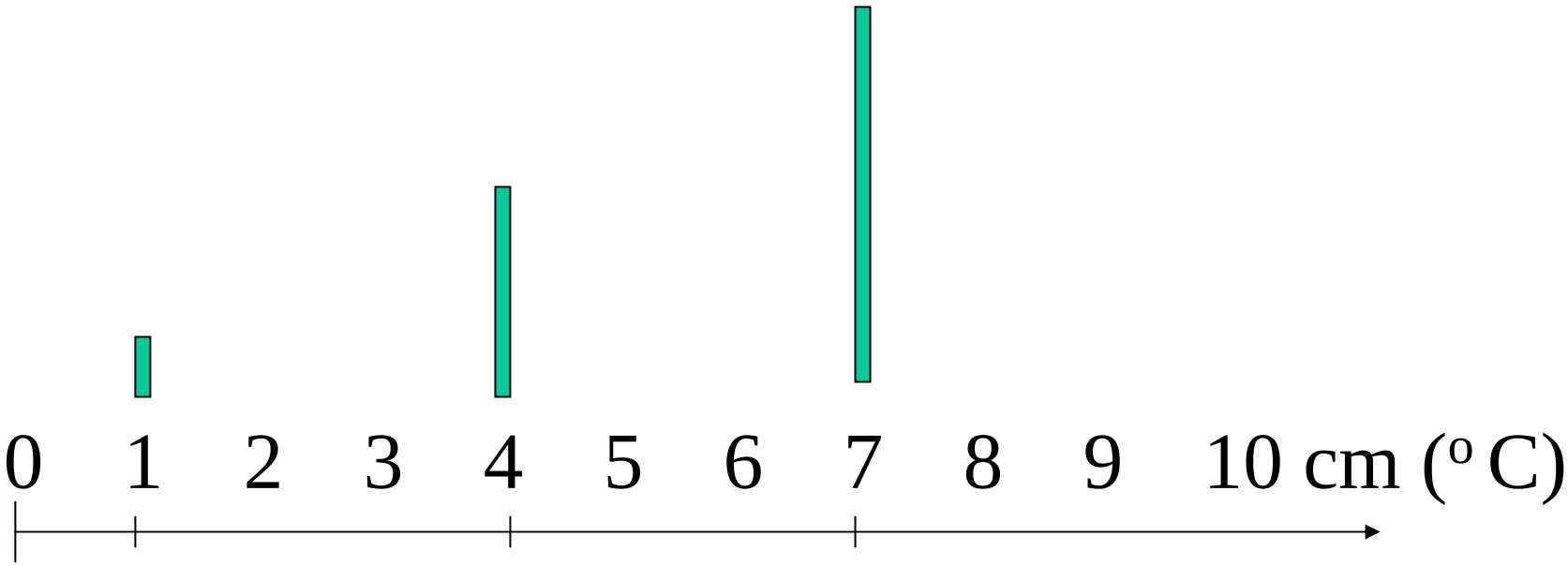


Scales (Conceptual Spaces)



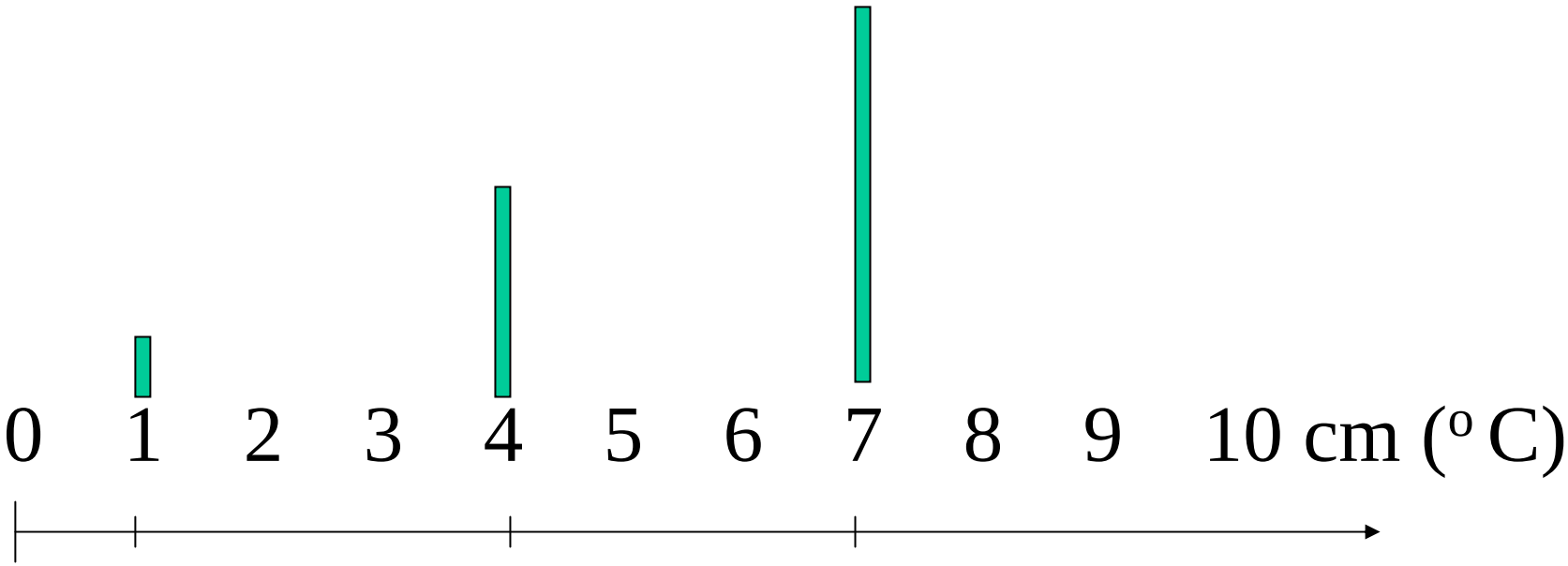
- A lot of things can be equally long; a lot of gases can have the same temperature.
- One thing may be longer than another; one gas may have a higher temperature than another.

Scales



(a) All scales presuppose a distinction between a determinable (a conceptual space) and its determinates (the points in the space).

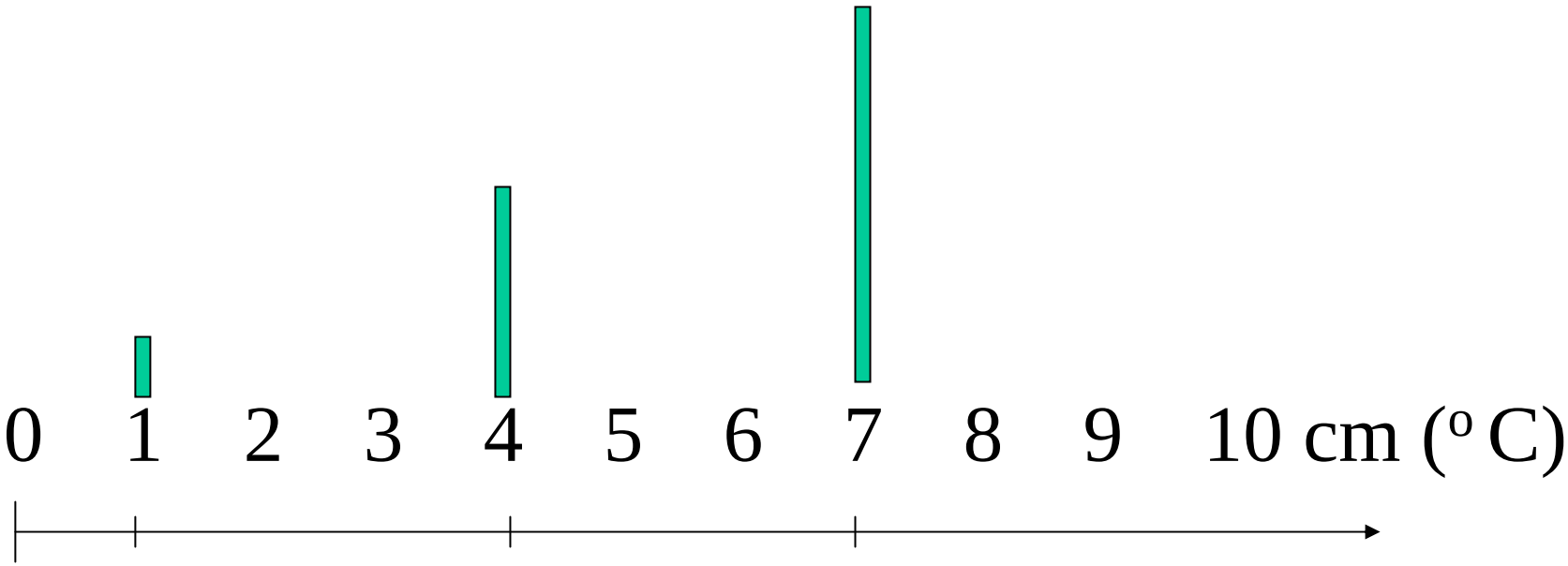
Ordinal Scales



7 cm (° C) is more like 4 cm (° C) in length (temperature) than 1 cm.

(b) An ordinal scale represents only resemblance relations between determinates of a d-able.

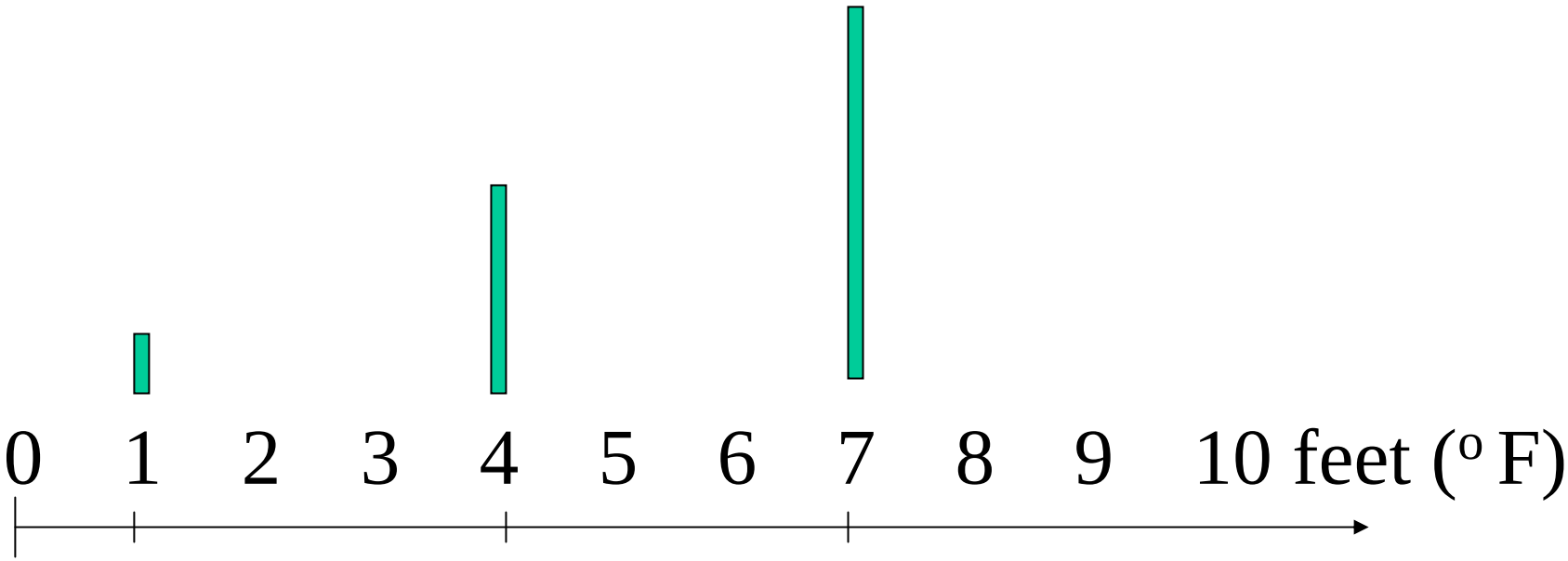
Metric Scales (i)



7 cm differs from 4 cm just as much as 4 cm differs from 1 cm.

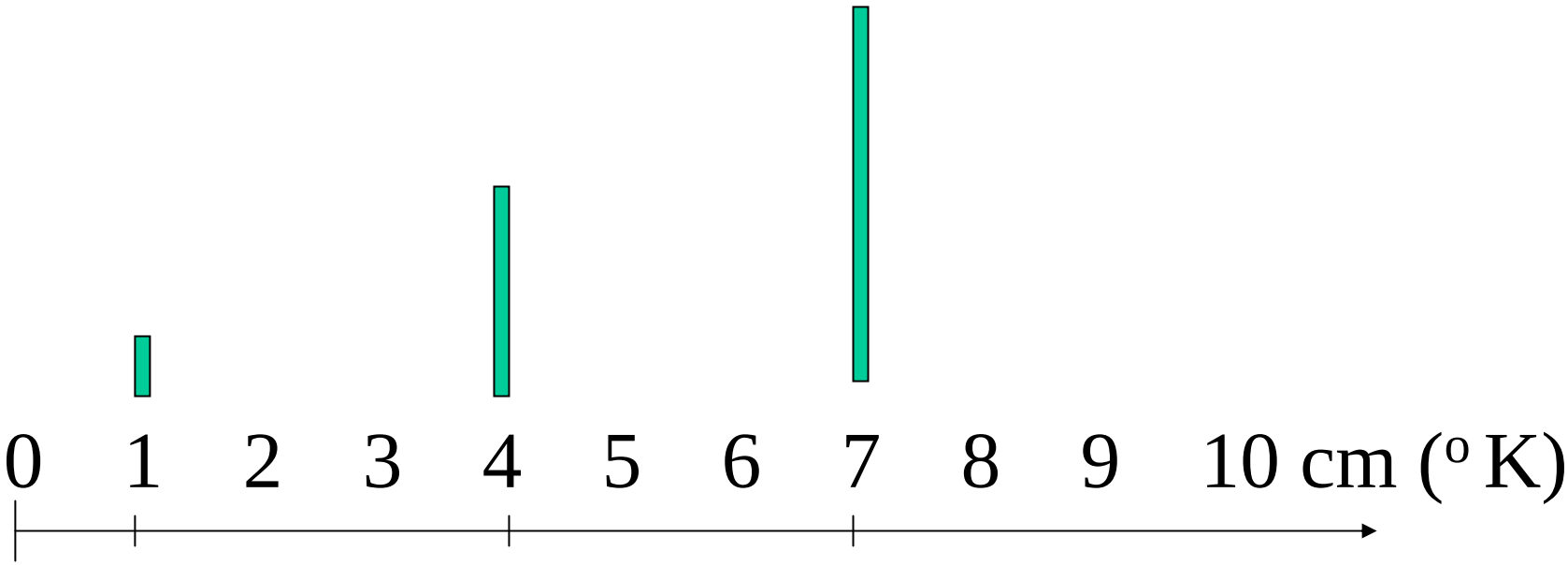
(c) A metric scale represents distance relations between determinates, too.

Metric Scales (ii)



(d) A metric scale has a fiat standard unit, i.e., a metricizable determinable has many possible scales.

Metric Scales (iii)



(d) Some metric scales have an absolute zero point (ratio scales, ° K), some have a fiat zero point (interval scales, ° C and ° F).

Speech Acts Using Quantities

- Every true statement such as “This thing has a length of 7 cm” and “This gas has a temperature of 7 ^{o} C” makes explicit use of one conceptual determinate and one conceptual determinable.
- However, such a statement also connotes:
  (i) all the determinates;
  (ii) all the corresponding resemblance relations and distance relations.

(4b) Temperature Scales

- Every true statement such as “The air in this room has a temperature of 19 ^{o}C” makes explicit use of one conceptual determinate and one determinable, but it refers to a language-independent non-conceptual determinate and its d-able.
- Temperature scales are used in order to refer to concept-independent temperatures.

Scales and Realism (i)

- Metric scales should be regarded as maps over resemblance-distance relations between non-conceptual determinates (universals).
- Measurements might be said to be mappings into a scale (an abstract conceptual space), but it is non-conceptual determinates that are being measured and mapped.

There are mountains

Complications for Naïve Realism

When, by means of a concept such as “mountain”, we are talking about something in the world, then this concept may:

- (i) **select** an aspect (e.g., geographical),
- (ii) **select** a granularity level (e.g., mesoscopic),
- (iii) **create** boundaries (ends of the mountains),
- without thereby
- (iv) create this aspect, the granularity level, and *what* is bounded (the mountain).

Scales and Realism (ii)

When, by means of a temperature scale, we are talking about a certain determinate objective temperature, then this scale:

- (i) **selects** an aspect (temperature as a d-able),
- (ii) **selects** a granularity range (mesoscopic),
- (iii) **creates** links (to the other determinates),
- but it does not thereby
- (iv) create this aspect, this granularity range, and *what* is directly talked about (the determinate temperature in question).

Temperature in Medicine

- Body temperatures (determinates and d-able) are objective features of the world.
- When there is a change in temperature, the temperature determinable remains the same (it cannot change), but one determinate is exchanged for another.
- Galen (129-210) invented the first thermometer.