La science en cuisinant:

L’art de la cuisson basse temperature…

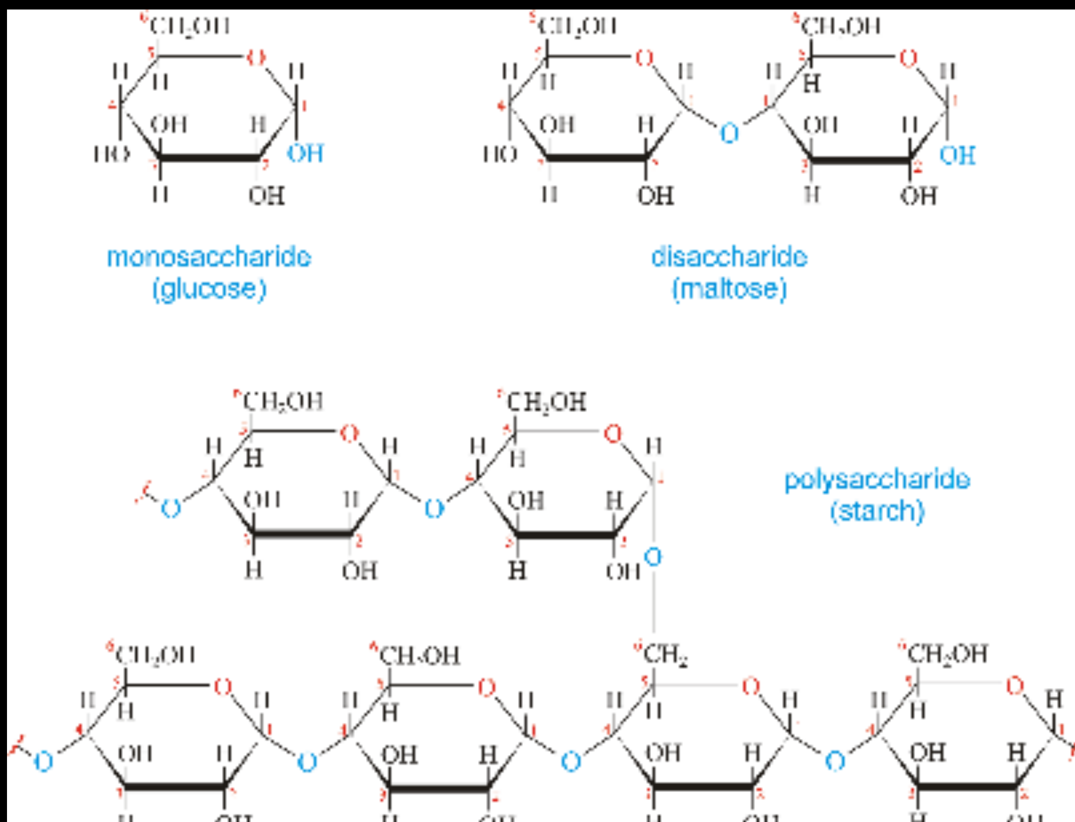
The 4 ingredients that makes food:

- Fats
- Carbohydrates
- Proteins
- Water
- Vitamins and Minerals

FATS

Do not dissolve in water

CARBOHYDRATES

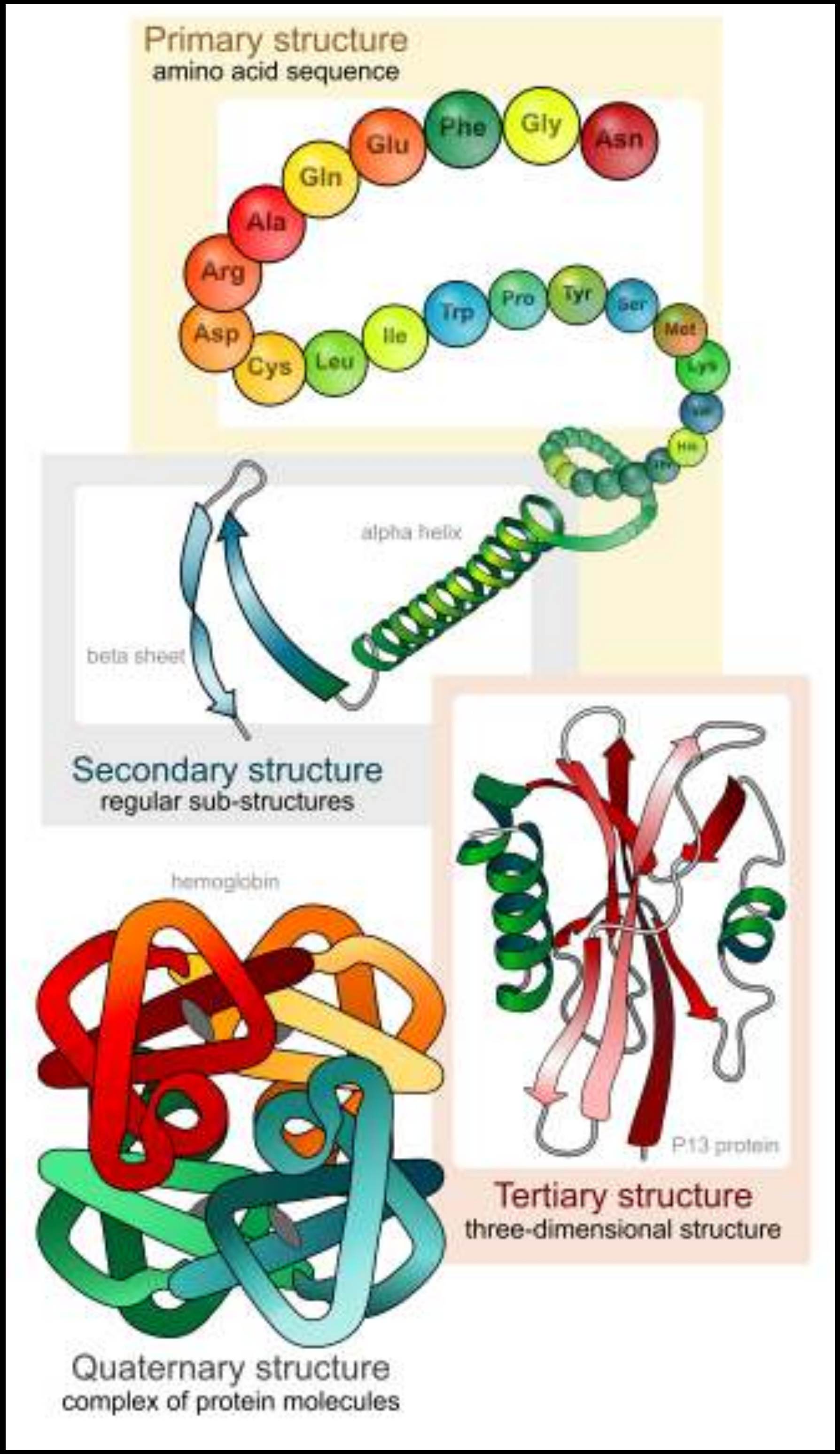


Sacarose: short chains

Maltose: short chains

Starch: long chains

PROTEINS



Proteins=chains of amino acids

20 different Amino Acids can be combined to form proteins.

Cooking

- Roasting
- Frying
- Steaming
- Smoking
- Baking
- Boiling
- Acidifying…

Preamble

Temperature: it represents the **kinetic energy** due to **microscopic agitation**.

$$E = k_B T$$

Heat: it represents the amount of **energy** you need to provide to a system to increase its temperature (**the microscopic kinetic energy**).

$$\Delta E = k_B \Delta T$$

Heating Power: **How fast** you can provide this energy to the system, i.e. how fast you can raise its temperature.

$$\mathcal{P} = \frac{\Delta E}{\Delta t} = k_B \frac{\Delta T}{\Delta t}$$

What is temperature ?

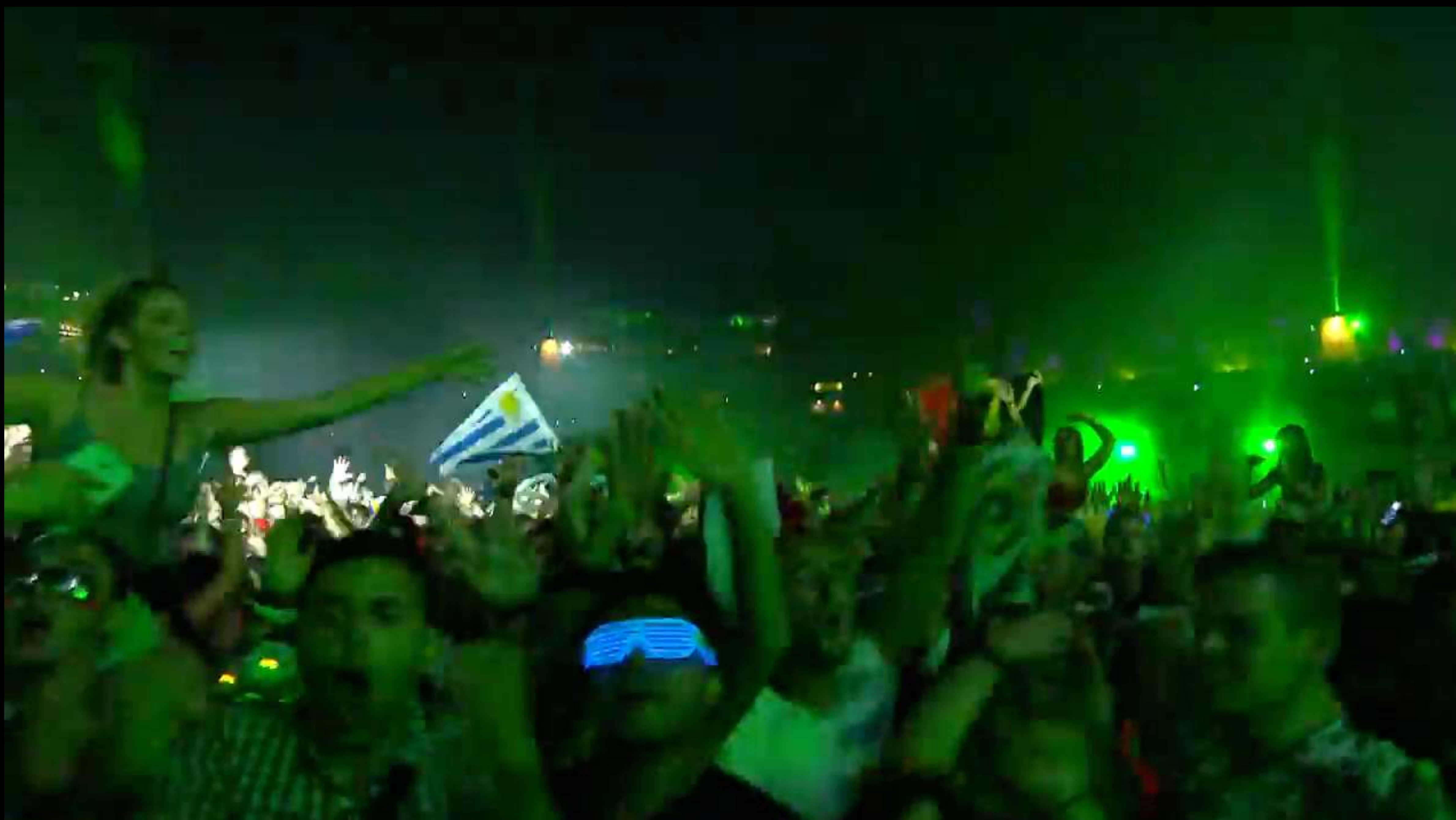
Temperature is a measure of the kinetic energy due to agitation of the molecules and atoms at the microscopic scale.

$$E = k_B T$$

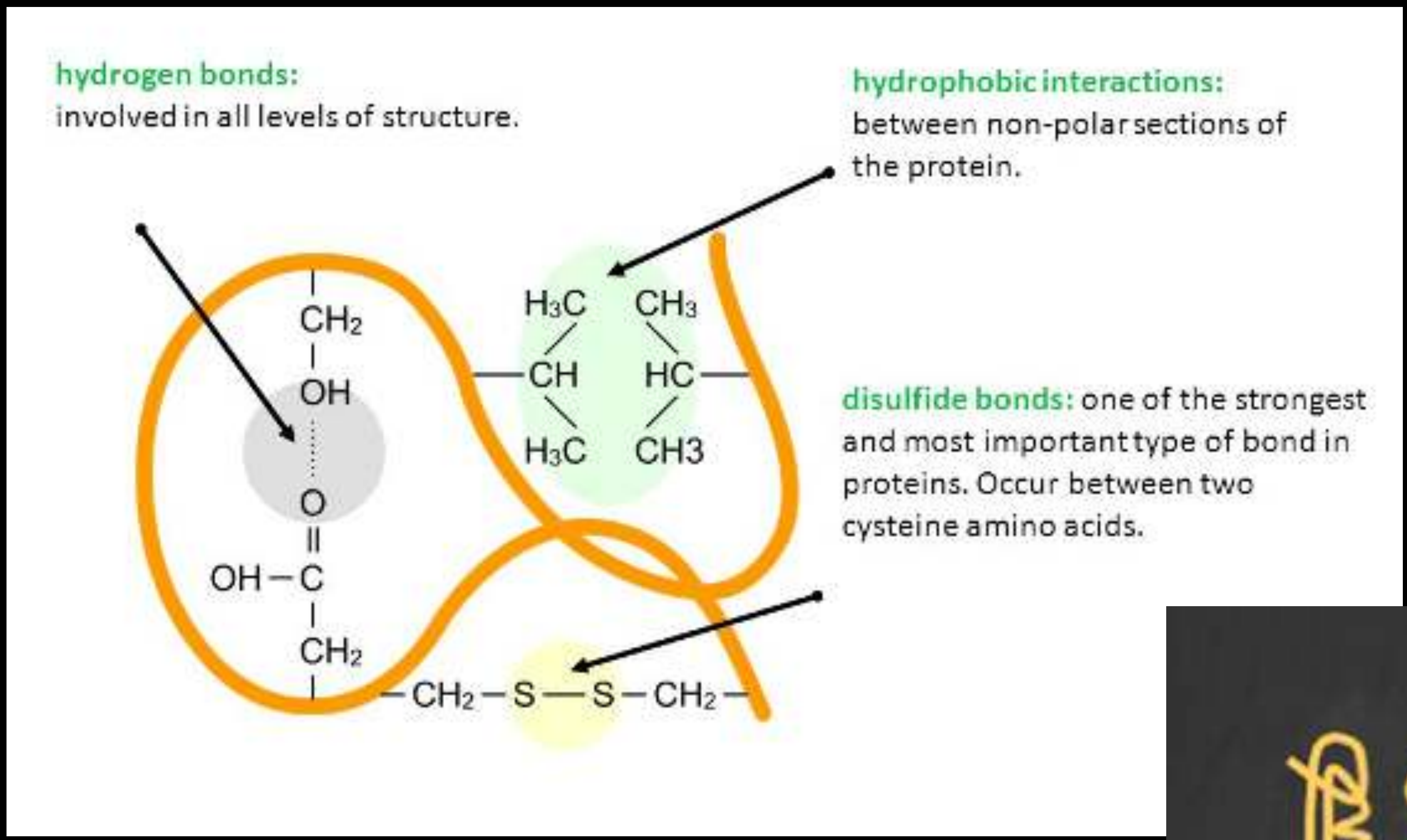
k_B is the Boltzmann constant.

What is temperature ?

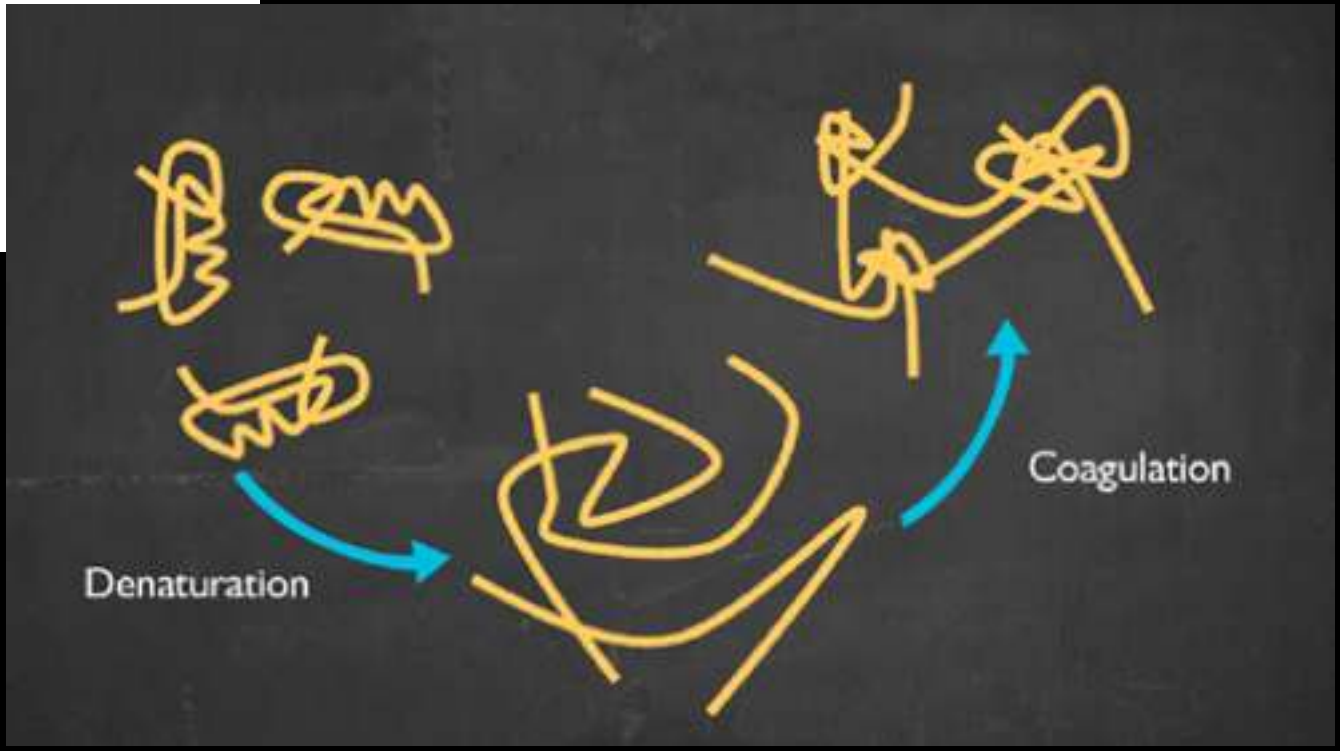
$$E = k_B T$$



Cooking=denaturation of the proteins

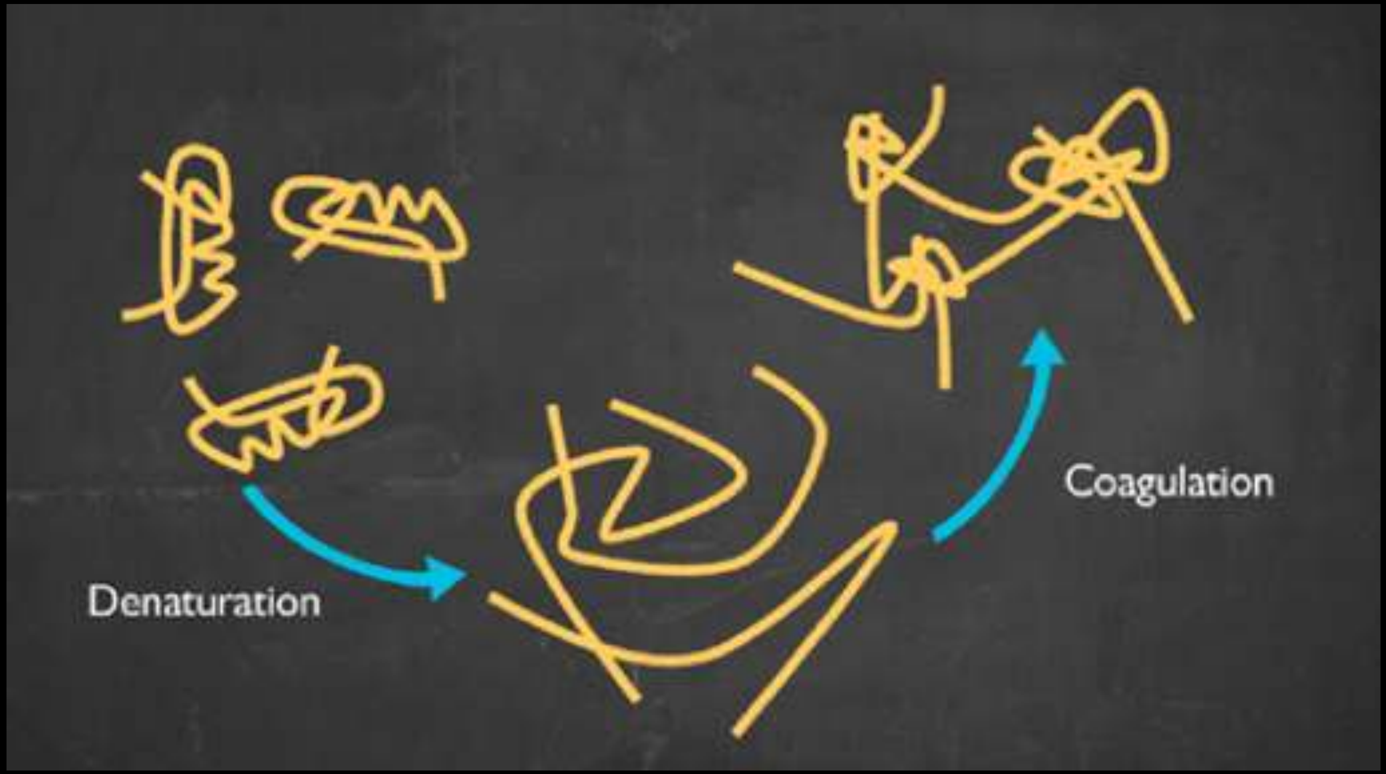


$$E = k_B T$$



Cooking=denaturation of the proteins

As we heat food, the proteins will progressively unfold and coagulate, leading to various textures at very specific temperatures.



$$E = k_B T$$

Each protein has a different temperature of denaturation.

What is happening when you cook an egg ?

Egg ≈ 119 different proteins

The various texture of a boiled egg

At 57°C the egg is fully pasteurised but no denaturation has occurred yet.

Courtesy of Harvard university: class book Science & Cooking / Online course

The various texture of a boiled egg

- **around 60°C the first proteins start to denature and cause the egg white to form a loose gel**

Courtesy of Harvard university: class book Science & Cooking / Online course

The various texture of a boiled egg

Between 62°C and 63°C, 1°C difference

Courtesy of Harvard university: class book Science & Cooking / Online course

The various texture of a boiled egg

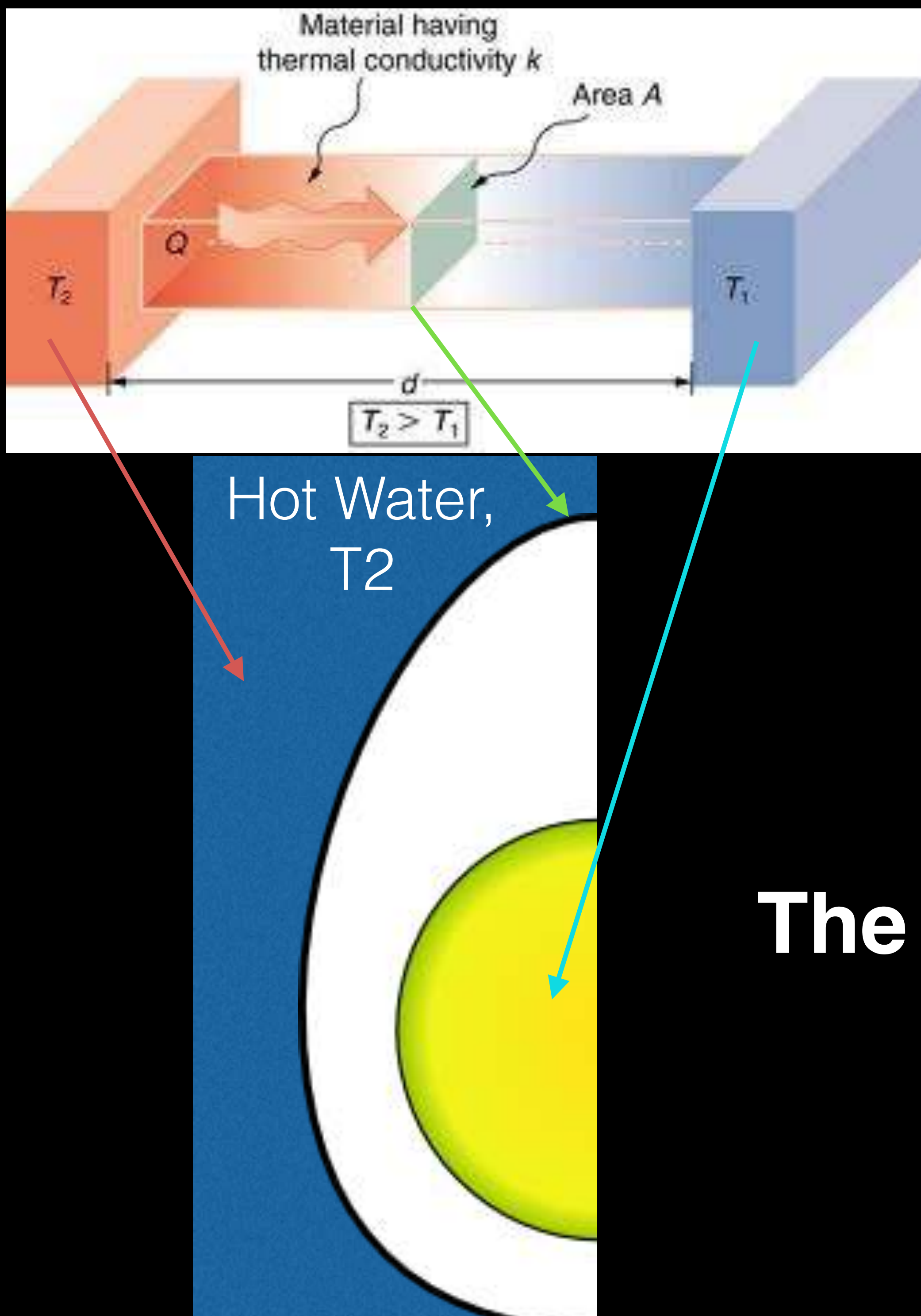
Courtesy of Harvard university: class book Science & Cooking / Online course

The various texture of a boiled egg

70°C

Heat transfer in food

Heat Versus Temperature



$$T_1 \rightarrow T_1 + \Delta T$$

$$Q = mC_p\Delta T$$

The ‘heating’ will stop when T1=T2

Thermal capacity

$$Q = m\boxed{C_p}(T_2 - T1)$$

Ingredient	Cp(J/gK)
water	4.18
Egg	3.18
Beef	2.5-3.2
Frogs Legs	3.68
Olive Oil	1.97

Air: 1(J/g K)

How is heat transferred ?

By conduction

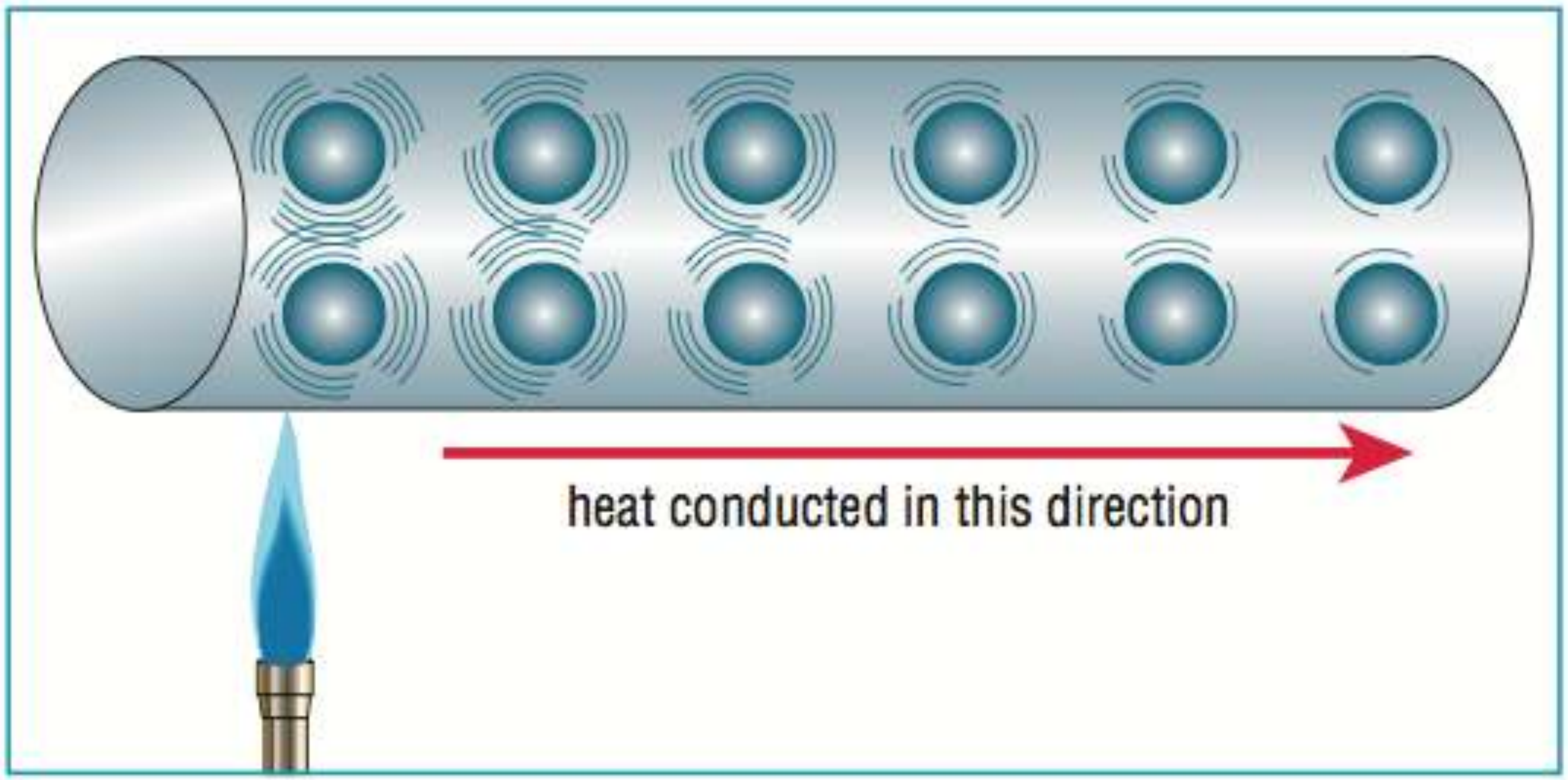
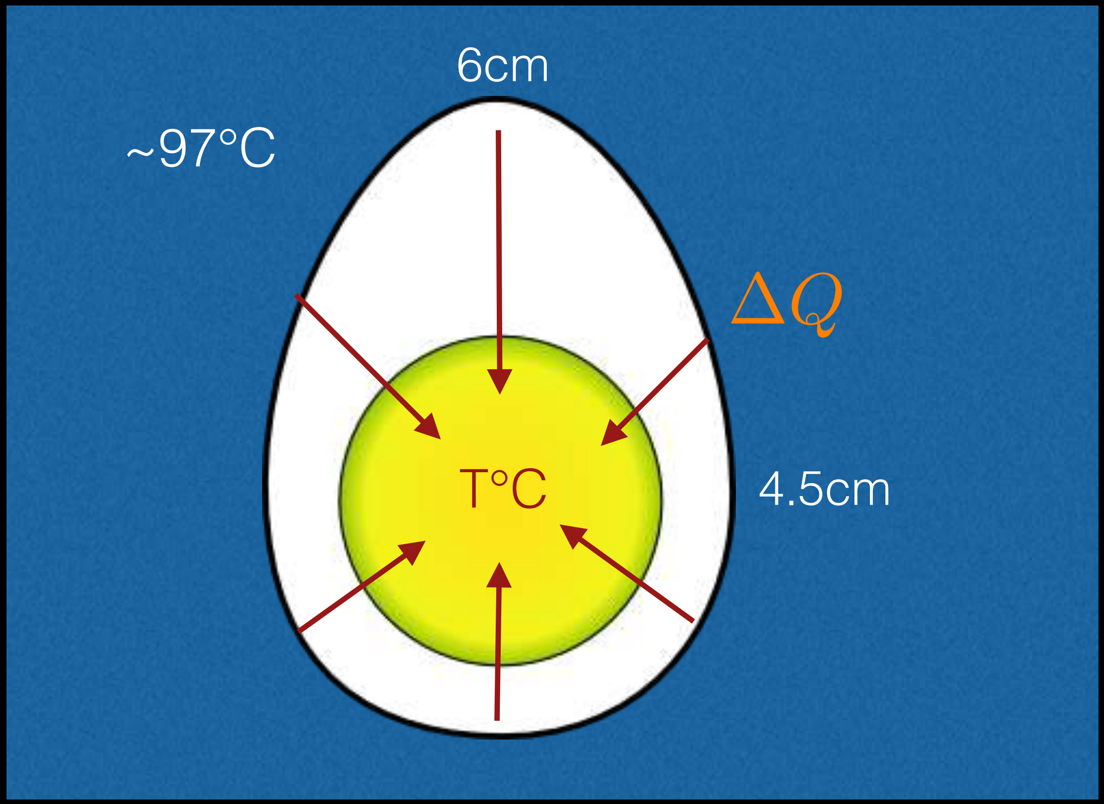


Fig 6.2.3 Conduction—vibrations pass along from particle to particle away from the heat source.

The Physics of the boiling egg



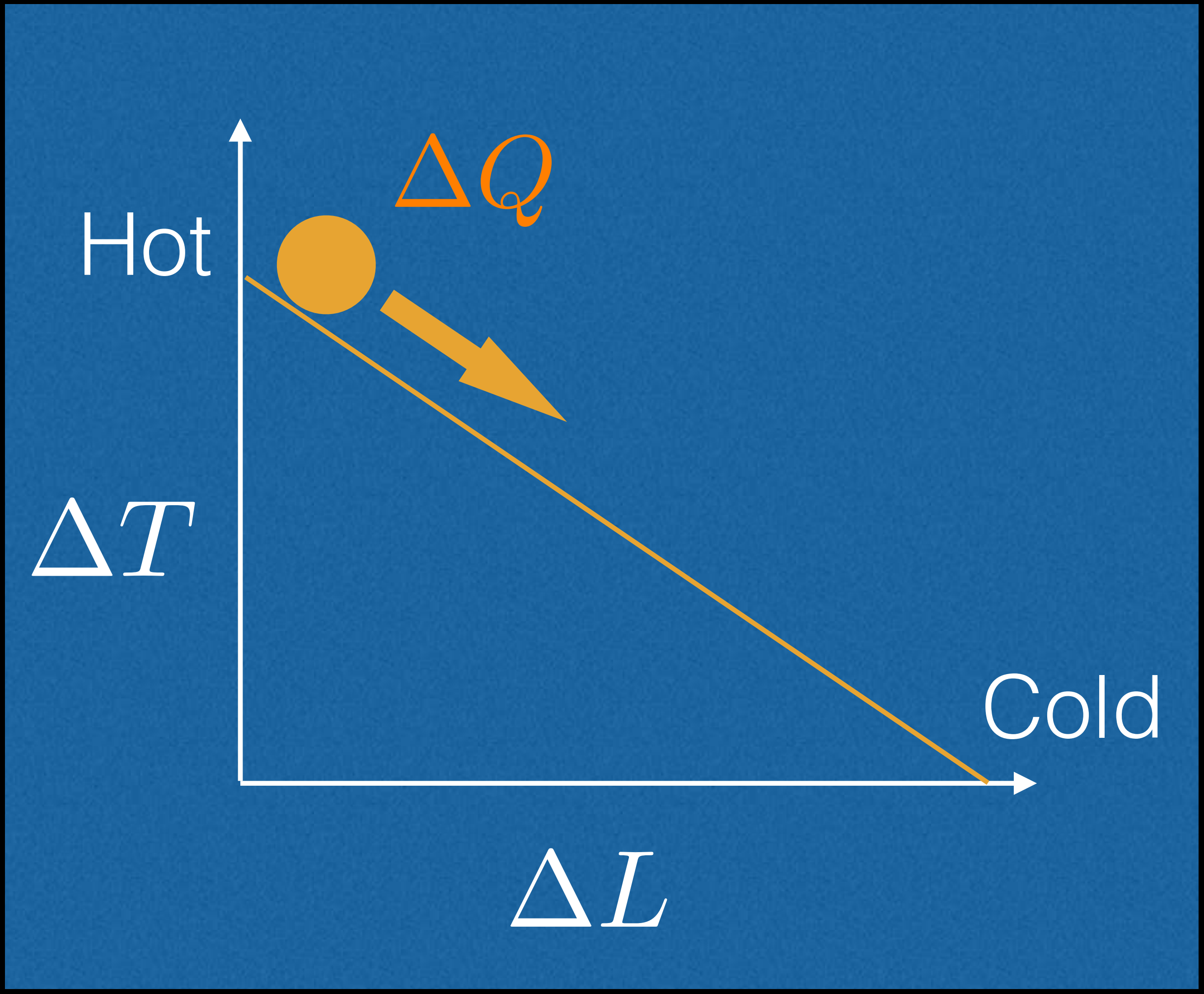
$$k_{egg} \sim 0.005\, W/cm/K$$

Heat equation:

$$\frac{\Delta Q}{\Delta t} = -k\frac{\Delta T}{\Delta L}S$$

k=Thermal conductivity

The Physics of the boiling egg



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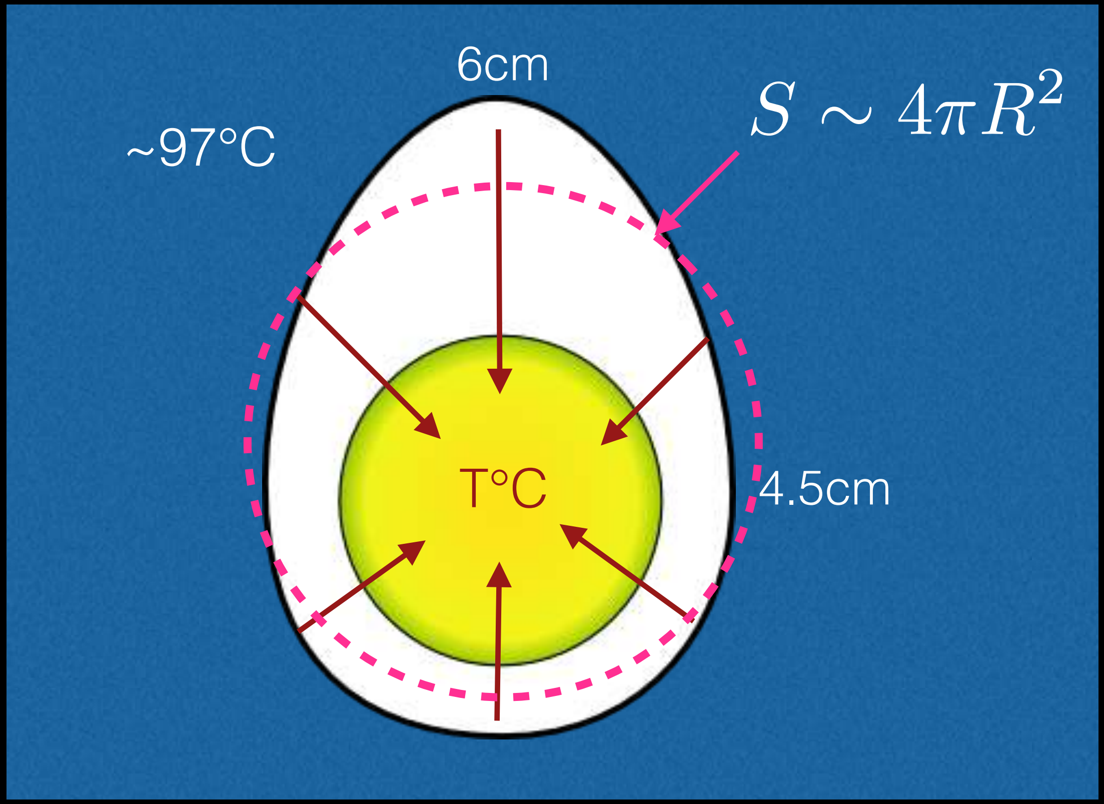
The Physics of the boiling egg



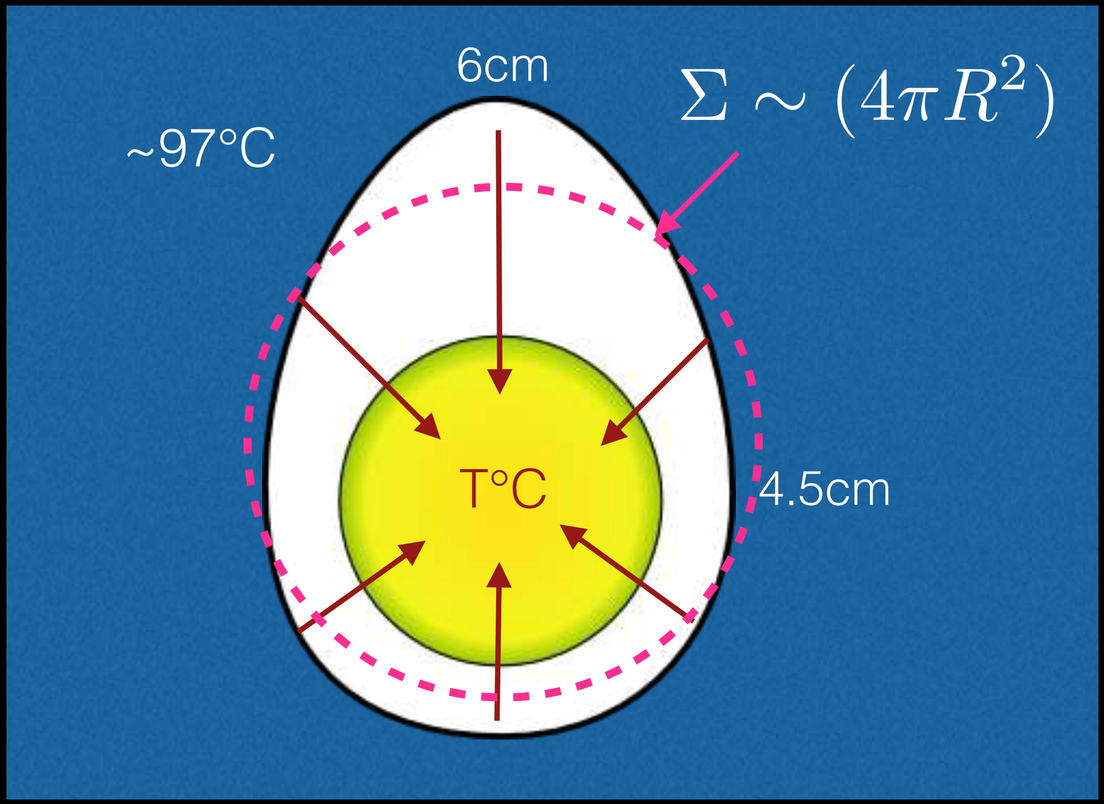
Heat equation:

$$\frac{\Delta Q}{\Delta t} = -k \frac{\Delta T}{\Delta L} S$$

$$\frac{\Delta Q}{\Delta t} = k 4\pi R \Delta T$$

The larger is the temperature gradient between the water and the yolk, the faster the heat is transported inside.

The Physics of the boiling egg



$$\frac{\Delta Q}{\Delta t} = k4\pi R\Delta T$$

$$\Delta Q = mC_p\delta T$$

The larger is the temperature gradient between the water and the yolk, the faster the temperature of the yolk increases .

The Physics of the boiling egg

Between 62°C and 63°C,
1°C difference

$k_{egg} \sim 0.005\, W/cm/K$

$R \sim 2.5\, cm$

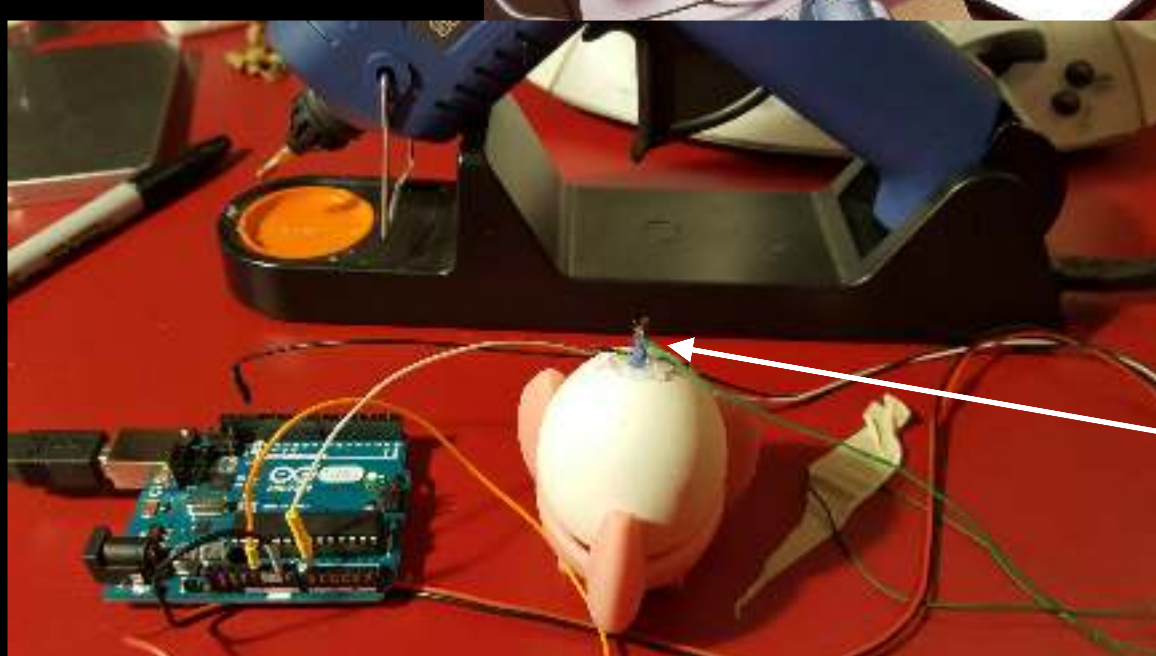
$m \sim 50g$

$Cp \sim 3.18 J/gK$

$$T_w \sim 80^{\circ}C \rightarrow \Delta t \sim 40s$$

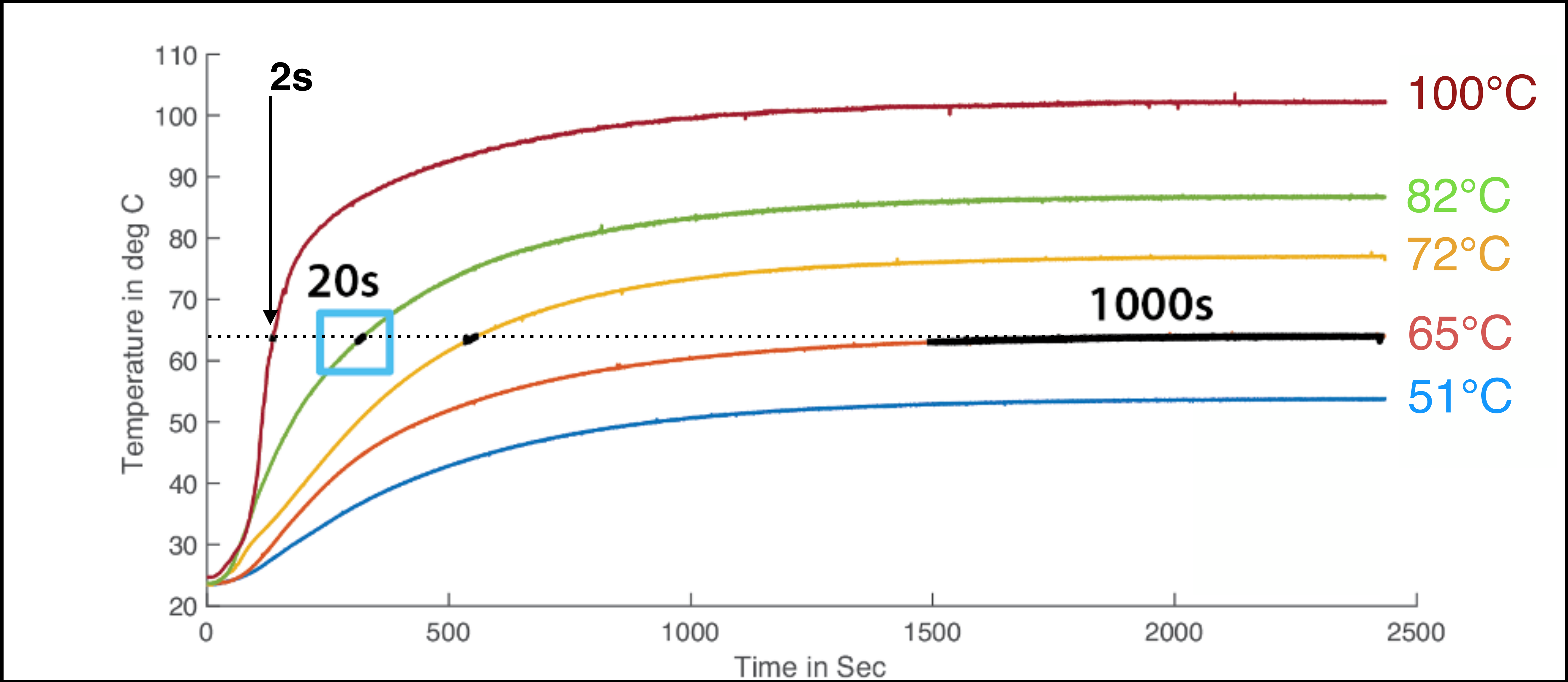
$$T_w \sim 64^{\circ}C \rightarrow \Delta t \sim 1000s$$

17 days and 36 eggs later



thermistor

How long does it takes to raise the temperature of the yolk from 62°C to 63°C?



$$T_w \sim 80^\circ C \rightarrow \Delta t \sim 40s$$

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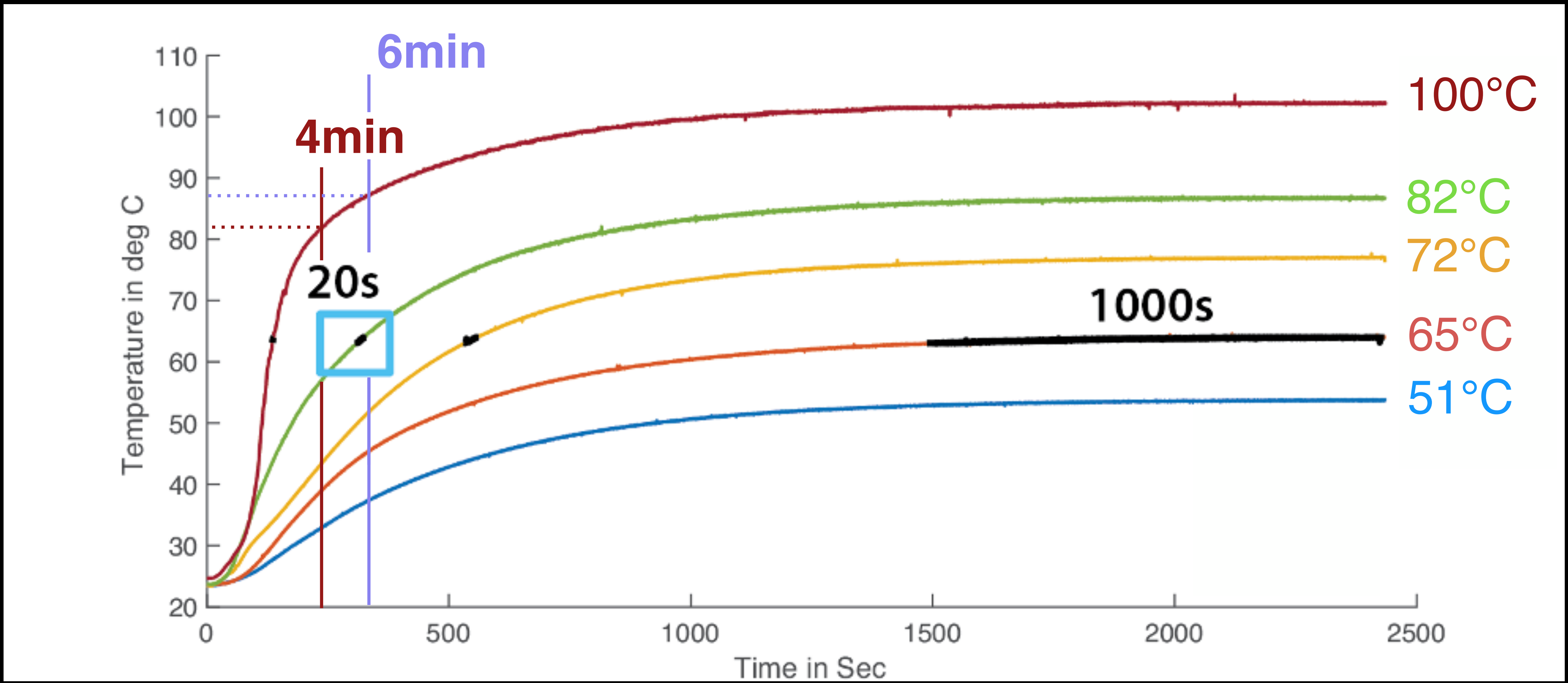
Boiling water cooking, the end of a myth…

How long does it takes to raise the temperature of the yolk from 62°C to 63°C?



$$T_w \sim 80^\circ C \rightarrow \Delta t \sim 40s$$

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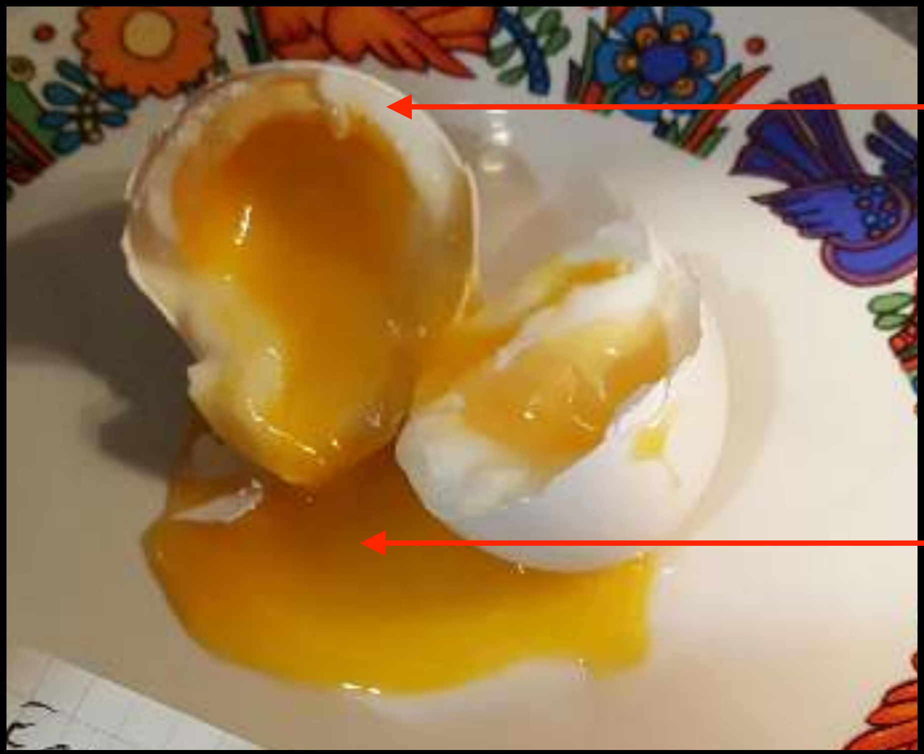
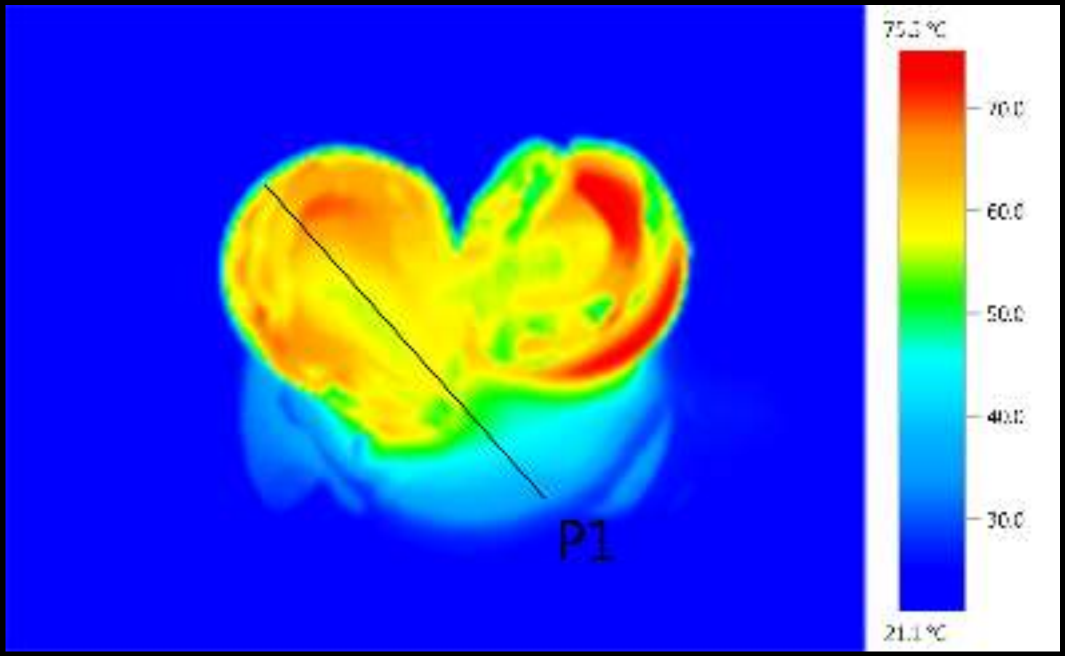
Boiling an Egg: 4 min

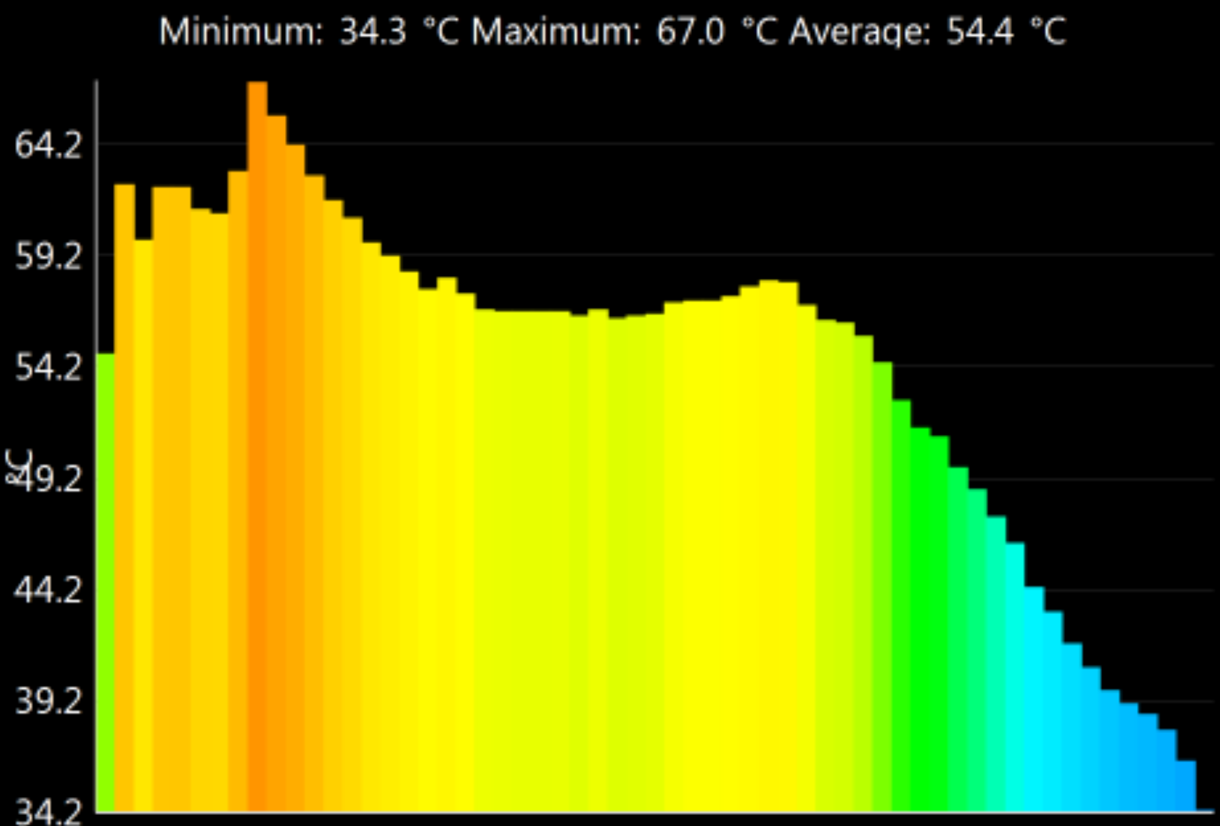


$T \sim 70°C - 80°C$

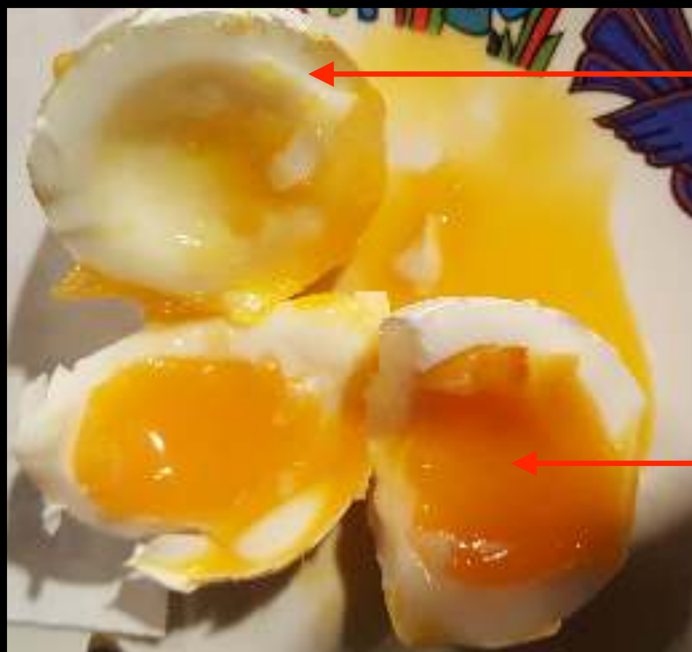
$T \sim 65°C$

After about 1min





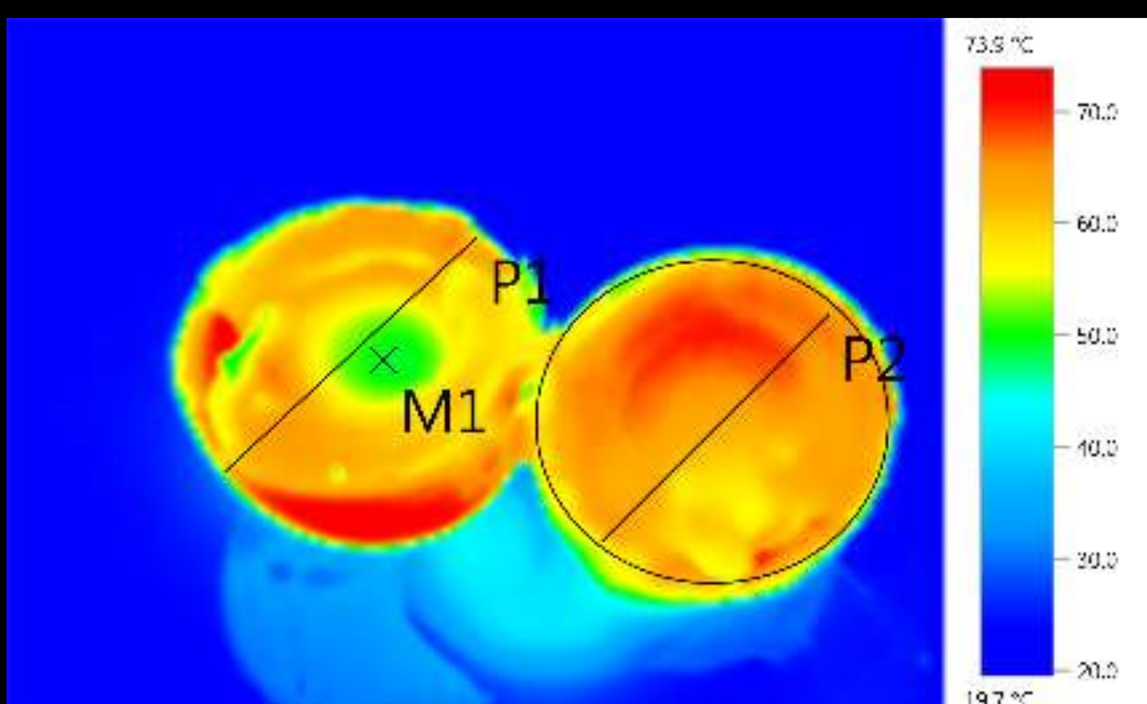
Boiling an Egg: 6 min

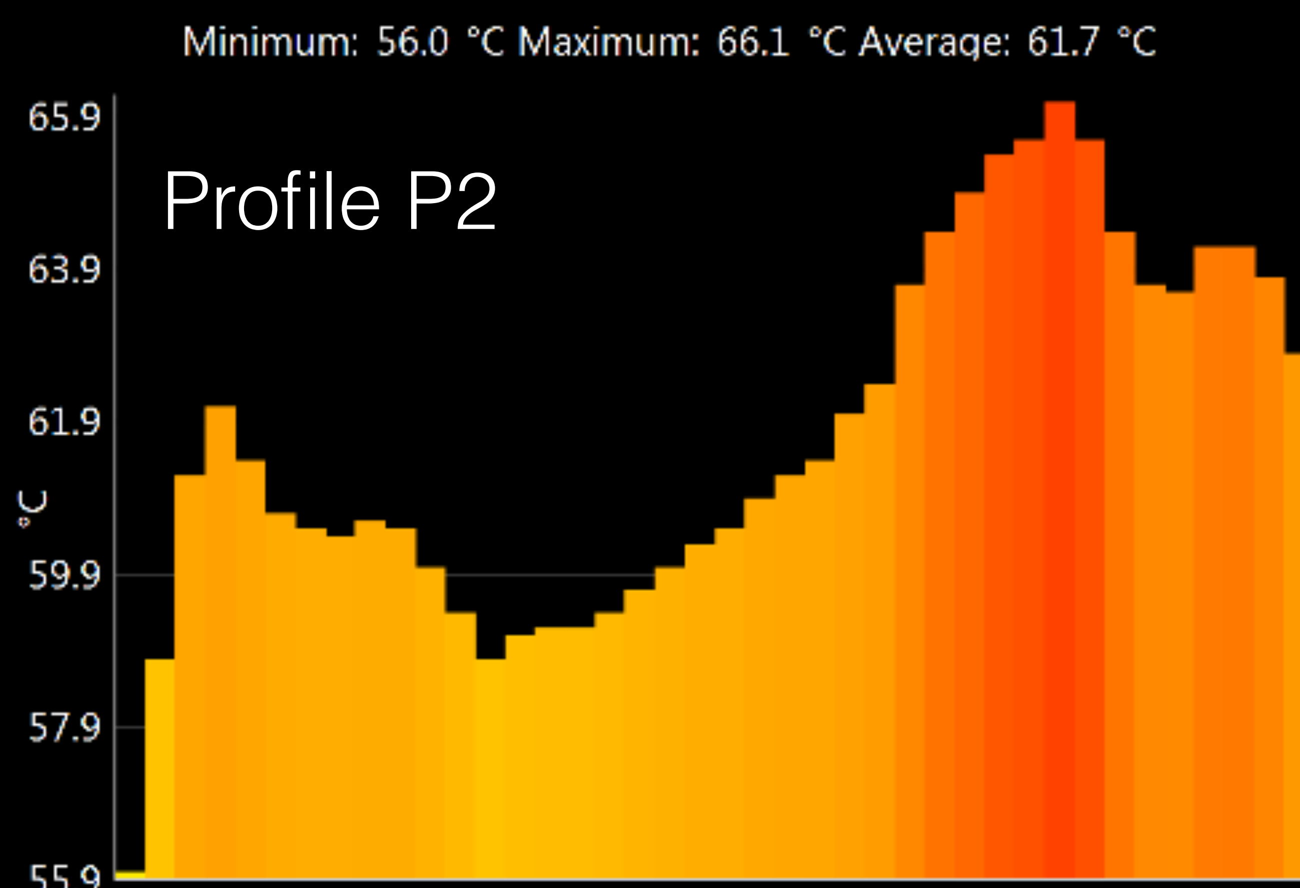


$T \sim 80°C$

$T \sim 67°C - 70°C$

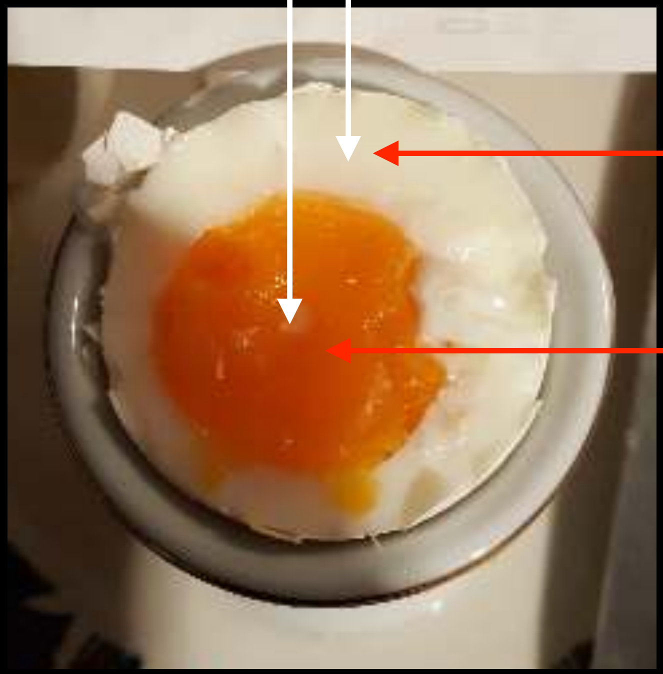
After about 1min





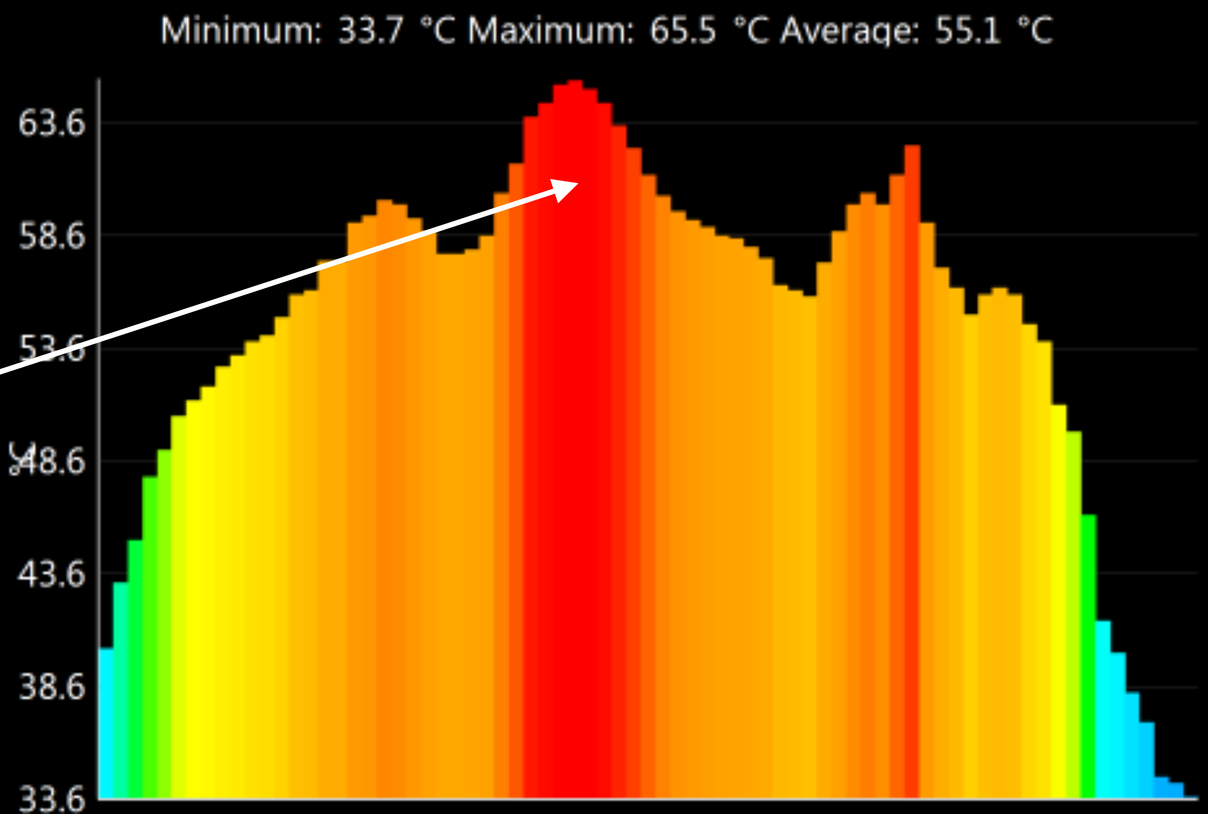
Boiling an Egg: 6 min + 4min rest

- (61.5°C): conalbumin the egg white -> loose gel
- (64.5°C): livetin the egg yolk -> tender gel
- (70°C): ovomucoid the egg white ->firm gel
- (84.5°C): ovalbumin the egg white -> rubbery.



$T \sim 67^\circ$

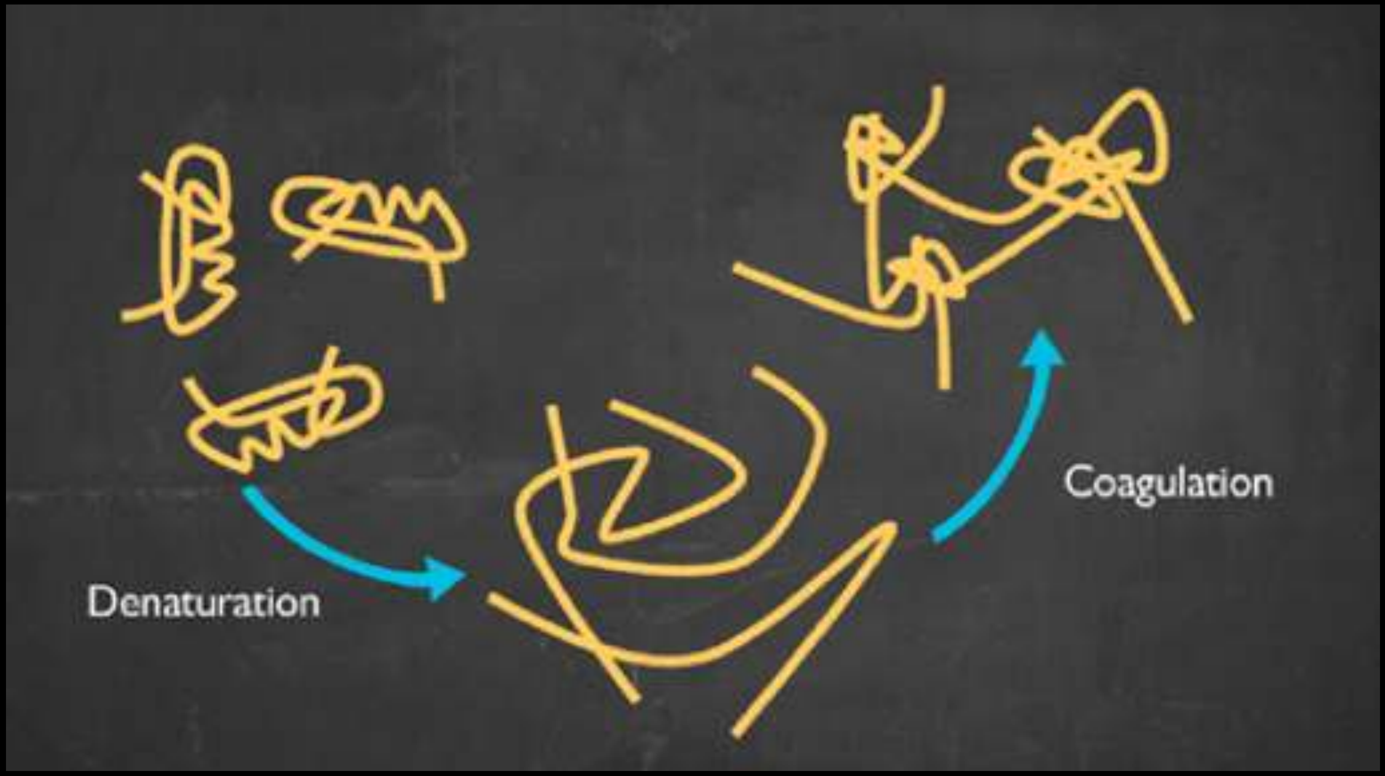
$T \sim 65^\circ C$



What is going on ????

Up to now we said: if $k_B T > E$ denaturation occurs.

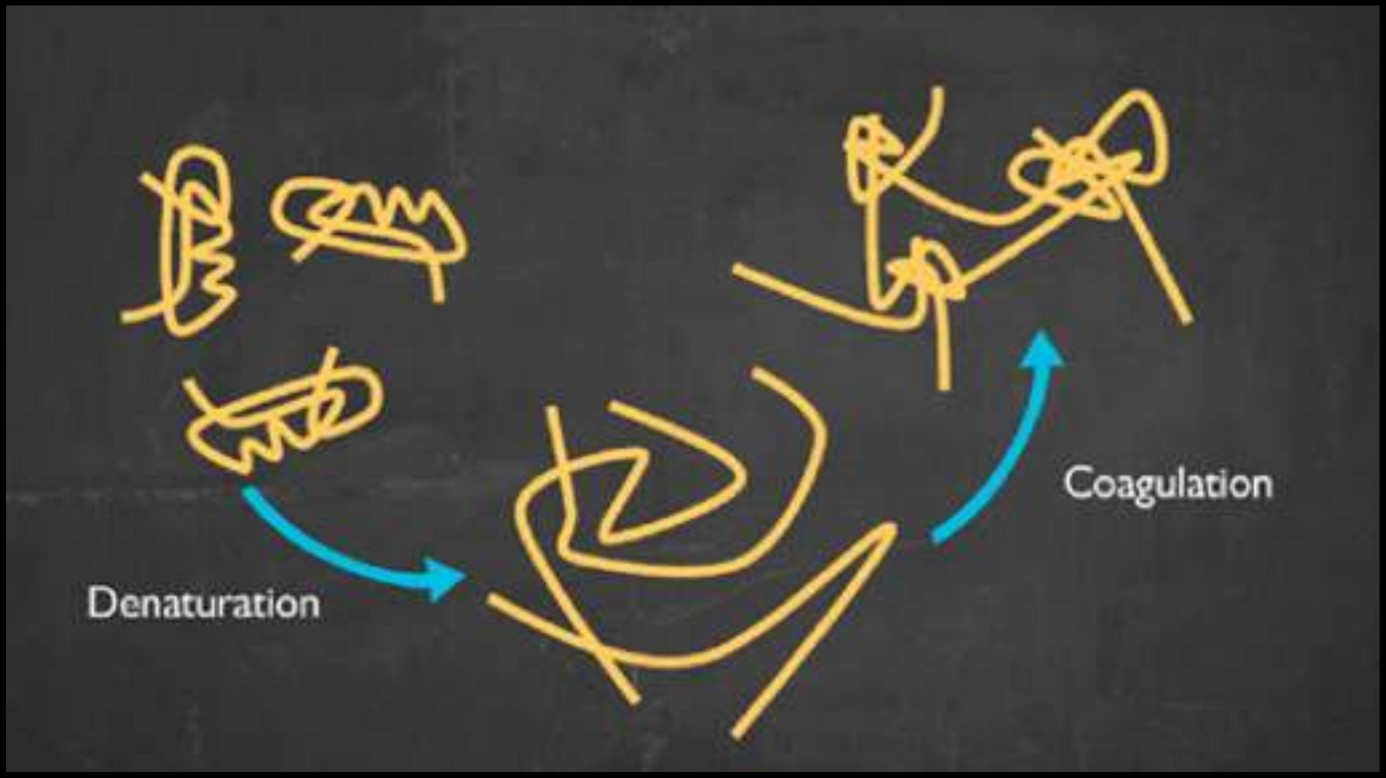
Actually, statistical physics tells that we should say:
There is a probability that it occurs.



$$P \propto exp(-\frac{E}{k_B T})$$

The higher the temperature, the higher is the probability you denatured the proteins.

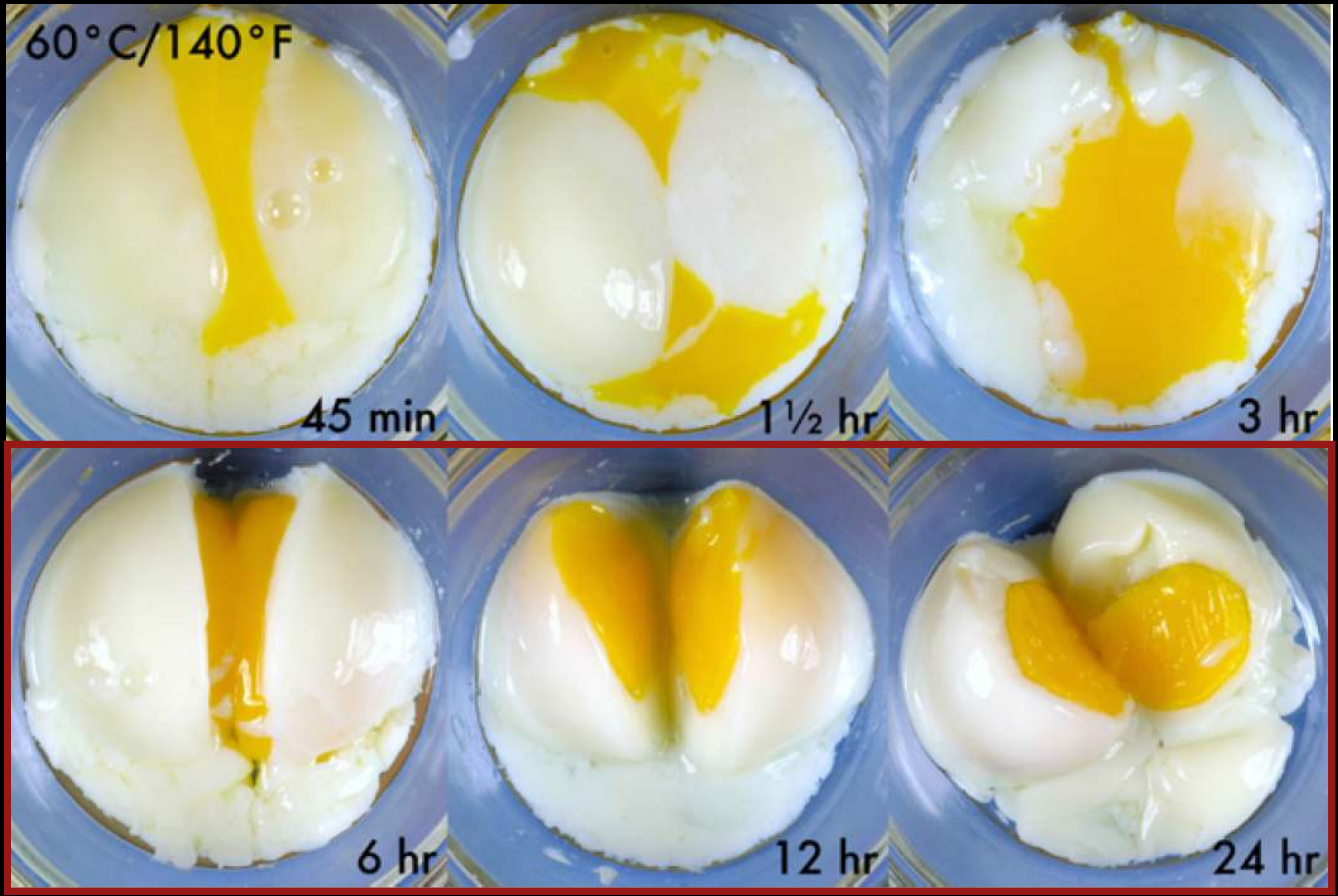
The higher the temperature, the faster you denatured the proteins.

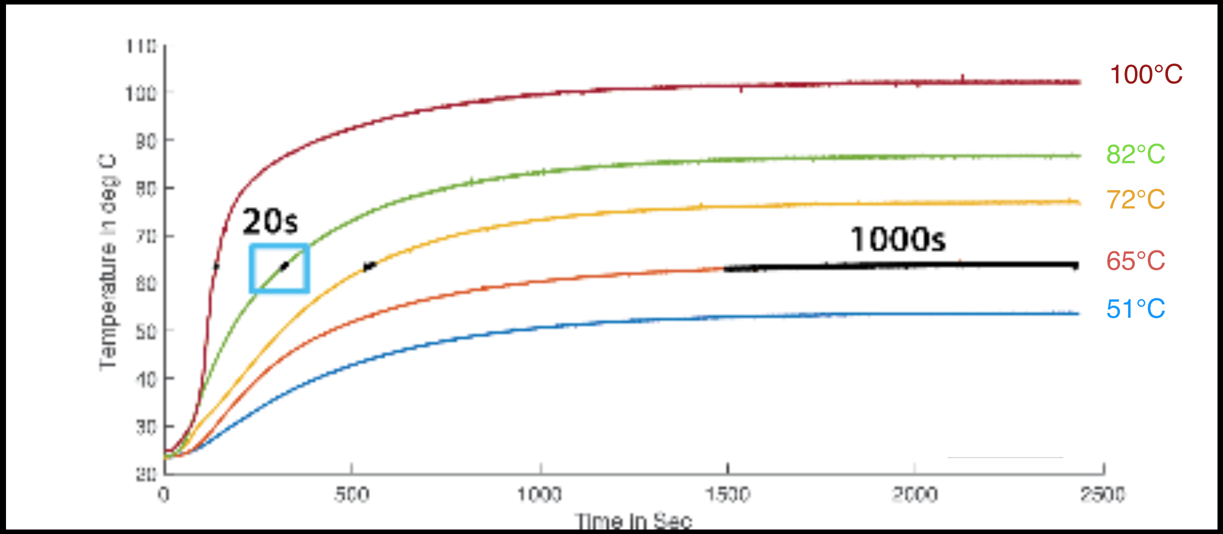


$$P \propto exp(-\frac{E}{k_B T})$$

From statistical physics, there is a small but non zero probability to denature the proteins at a temperature less than the typical activation energy !!!!!!

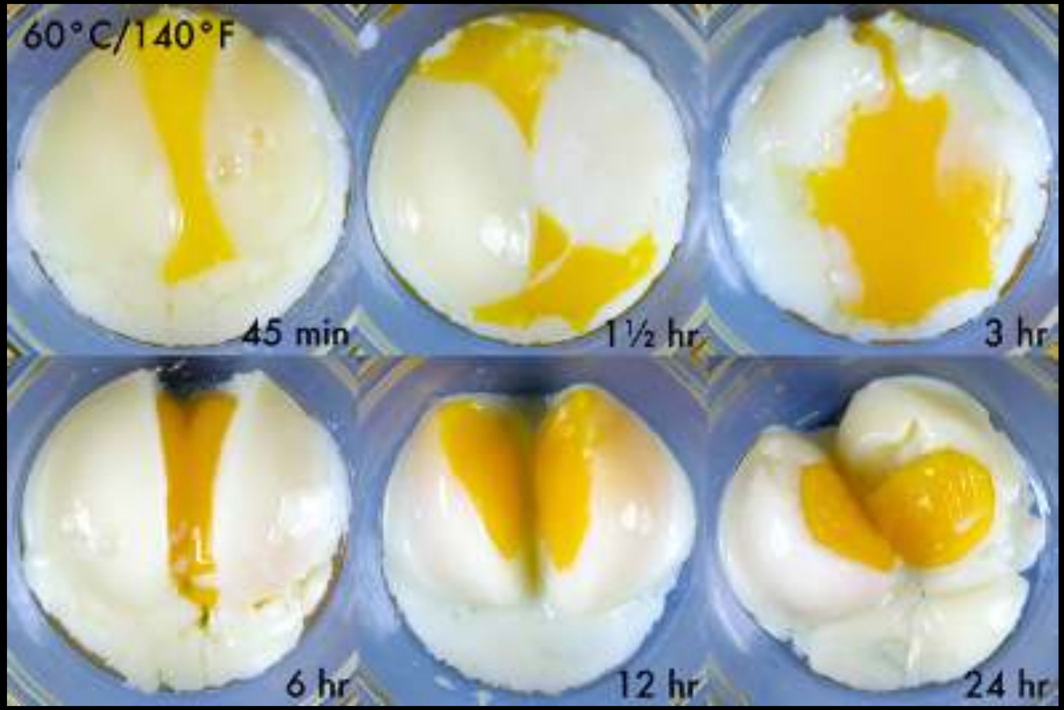
From statistical physics, there is a small but non zero probability to denature the proteins at a temperature less than the typical activation energy !!!!!!





high temperature cooking:
impossible to control the
denaturation precisely

Cooking just at the right temperature
for long enough allows for consistant
results with a specific texture.



Cooking for too long even at very
low T will result in the denaturation
of proteins you did not want to.

Cooking the perfect egg

Option 1

Option 2

Low Temperature (70°C) cooking allows for more control of the temperature.

$$\Delta T \sim 1°C \longrightarrow \Delta t \sim 2\,min$$

Low temperature vacuum cooking

Red wine beef short ribs with caramelised Savoy cabbage, glazed sweet carrots, parsnips & jus de Boeuf
by
Thomas Keller at Bouchon, Yountville, California

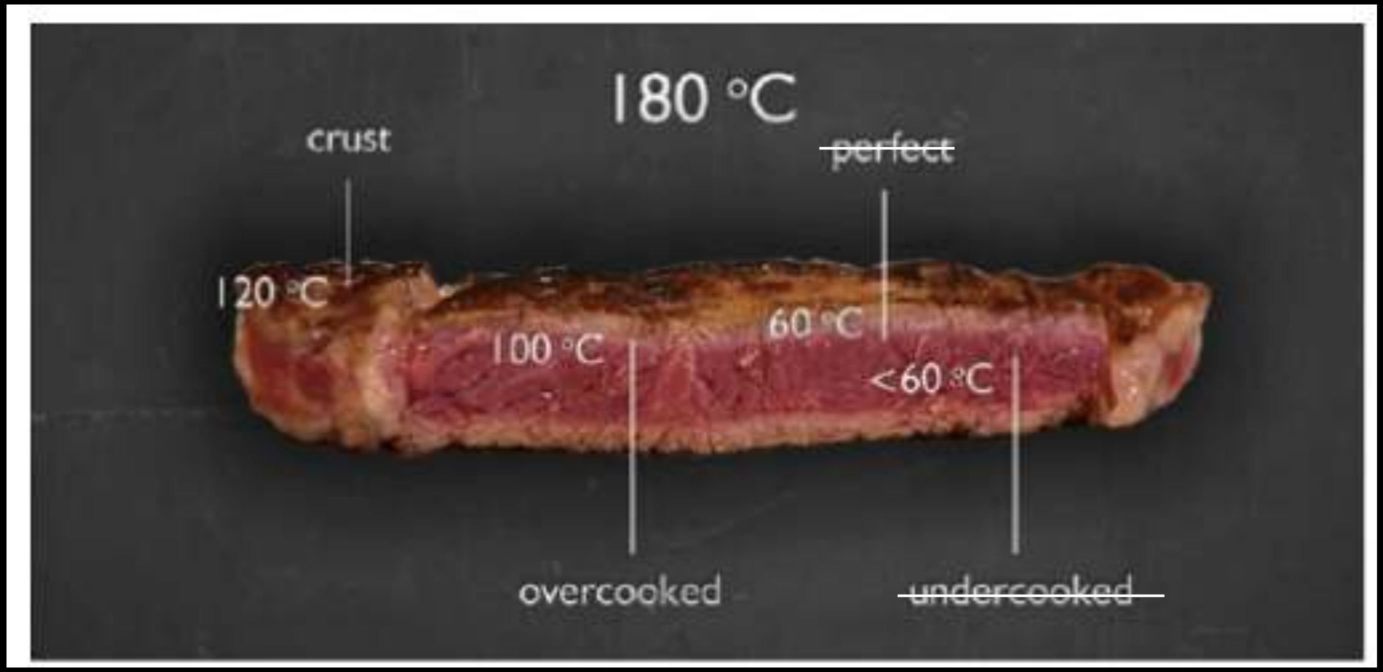
The Effects of Heat on Meat Proteins, Color and Texture

Meat Temperature	Doneness	Meat Qualities	Fiber Weakening Enzymes	Fiber Proteins	Connective-Tissue Collagen	Protein-Bound Water	Myoglobin Pigment
100°F 40°C	Raw	-Soft to touch -Slick, smooth -Translucent, deep red	Active	Beginning to unfold	Intact	Begins to escape from proteins, accumulate within cells	Normal
110°F 45°C	*Bleu*						
120°F 50°C	Rare, 120-130°F	-Becoming firmer -Becoming opaque	Very active	Myosin begins to denature, coagulate		Escape and accumulation accelerate	
130°F 55°C	Medium rare, 130-135°F	-Resilient to touch -Less slick, more fibrous -Releases juice when cut - Opaque, lighter red	Denature, become inactive, coagulate	Myosin coagulated	Collagen sheaths begin to weaken		
140°F 60°C	Medium, 130-145°F	-Begins to shrink -Losing resilience -Exudes juice -Red fades to pink		Other fiber proteins denature, coagulate	Collagen sheaths shrink, squeeze cells	Flows from cells under collagen pressure	Begins to denature

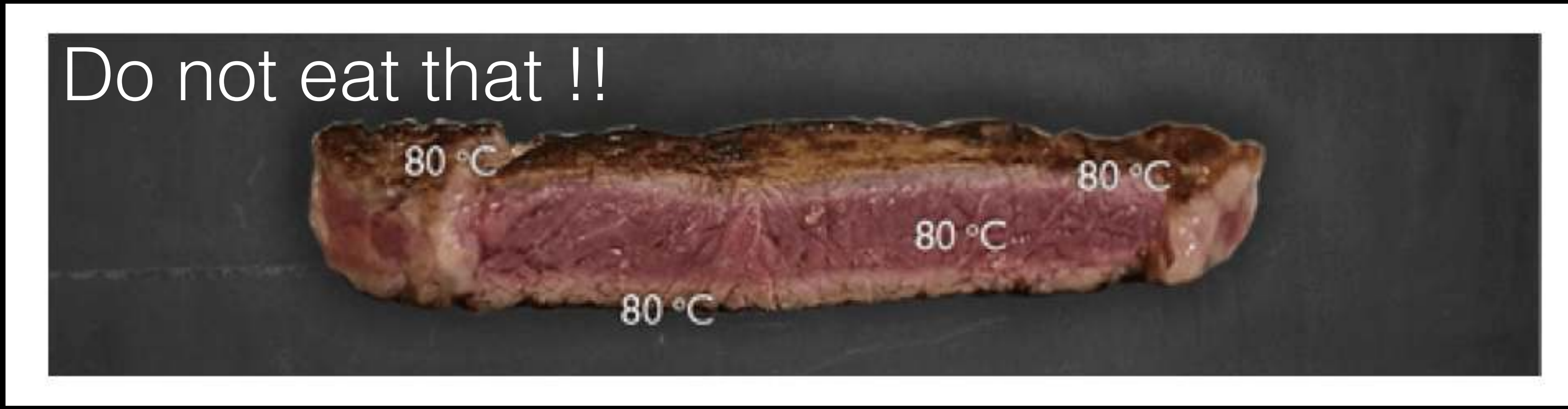
Courtesy of Harvard university: class book Science & Cooking / Online course

High temperature cooking:

- **Large temperature gradient**
- **No control on the final temperature**



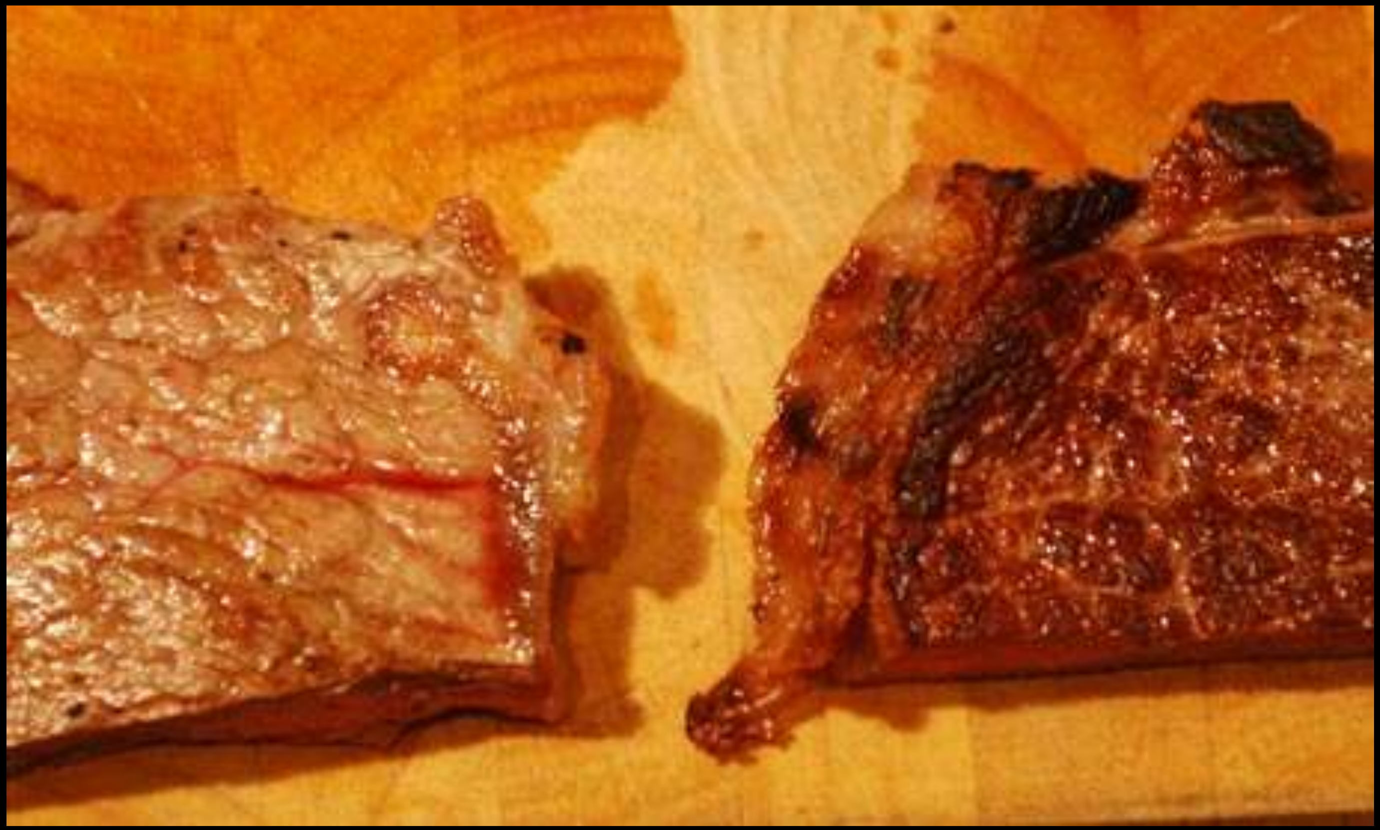
50°C: rare
55°C: medium rare
60°C: medium
>60°C: not an option



The Maillard reaction, the key to a tasteful steak.

Louis Camille Maillard (1878-1936)

In 1912 Maillard discovered that around 120°C-165°C, sugars and amino acids will combine to form complex molecules that are responsible for the odors and flavors of our cooked food.



The Maillard reaction, a high temperature stage in the cooking process.

Pan seared

High Temperature Oven

Low temperature cooking:

Vacuum

+

1h-2h cooking

+

Maillard

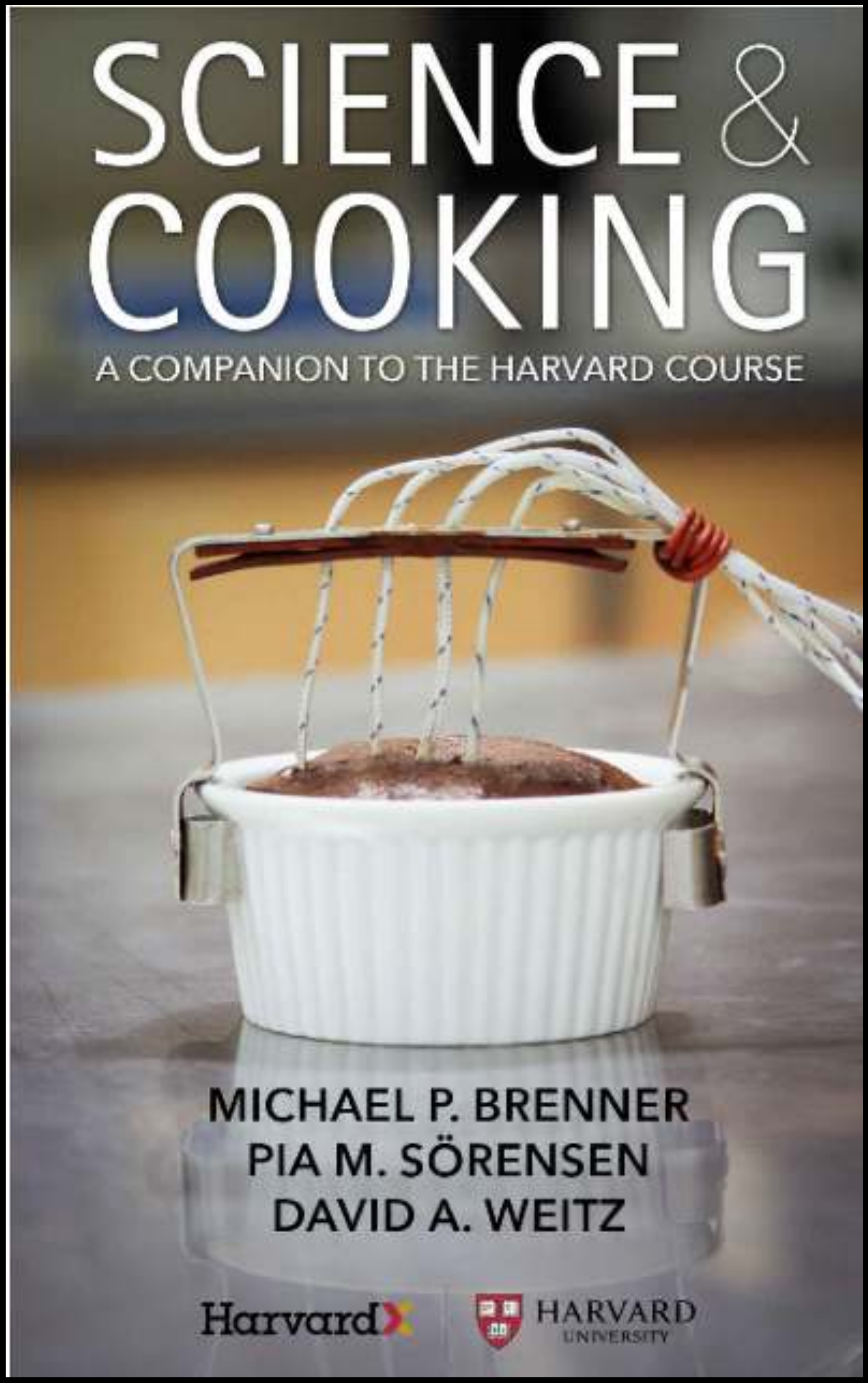
Maillard

+

Oven at Low Temperature (~<80°C)

+

55°C-57°C (~1h)



Online course:

HarvardX: SPU27x Science & Cooking: From Haute Cuisine to Soft Matter Science

Low temperature cooking:

http://www.cuisinebassetemperature.com/tableau-recapitulatif-de-cuisson-a-basse-temperature/

Tableaux de cuisson basse température et sous vide

Tableaux de cuisson FOUR TRADITIONNEL à basse température

Tweeter

www.cuisinebassetemperature.com Philippe Baratte, Votre Chef toqué du thermomètre

BŒUF	SAISIR	DURÉE MOYENNE DE CUISSON FOUR TRADITIONNEL	T° DU FOUR	T° A CŒUR
CÔTE (1,800 kg)	5 min	2½ heures	80°c	56°C (à point)
CÔTES COUVERTES (800 g)	4 min	2 heures	80°C	56°C (à point)
EMINCE (800 g – 4 portions)	30sec/portion	35 min	55°C	
ENTRECÔTES (200 g)	1 min	40 min	80°C	55°C (à point)
ENTRECÔTES DOUBLES (400 g)	1½ min	1 heure	80°C	55°C (à point)
FILET (800 g)	4 min	1½ heure	80°C	55°C (à point)
MEDAILLONS (100 g)	1 min	35 min	75°C	55°C (à point)
PAUPIETTES (150g)	1 min	45 min	75°C	66° C
PAVES (200 g)	1½ min	45 min	80°C	55°C (à point)
RÔTI (800 g)	4 min	2 heures	80°C	55°C (à point)
RÔTI (2 kg)	10 min	3 heures	80°C	55°C (à point)
RUMSTECK (800 g)	4 min	2 heures	80°C	55°C (à point)
STEAKS (200 g)	1 min	45 min	75°C	55°C (à point)

www.cuisinebassetemperature.com Philippe Baratte, Votre Chef toqué du thermomètre