

Physical bases of dental material science

Methodes of structure analysis
(Chapter 8.)

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Why is it important?

The macroscopic and microscopic structure strongly determines the physical, chemical and the biological properties and behaviour of materials.



in order to proper application we should know the structure

The materials can fail: fatigue, fracture, rupture, thermal shock, wearing, buckling → we have to recognize it

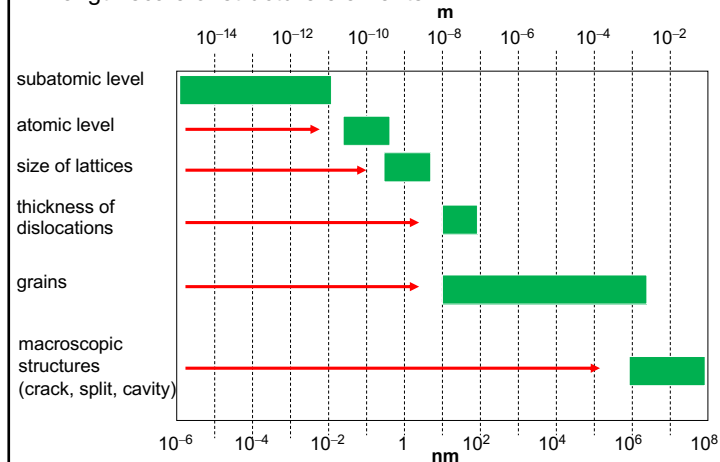
To improve our knowledge to develop the properties of materials



we have to analyse the structure

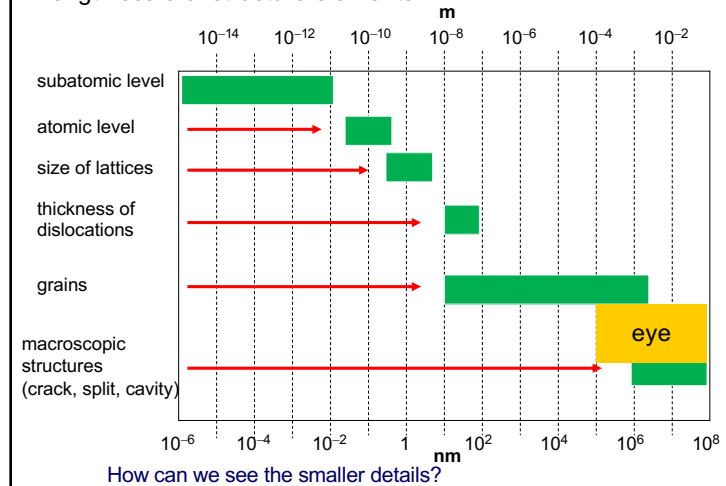
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Length scale of structure elements

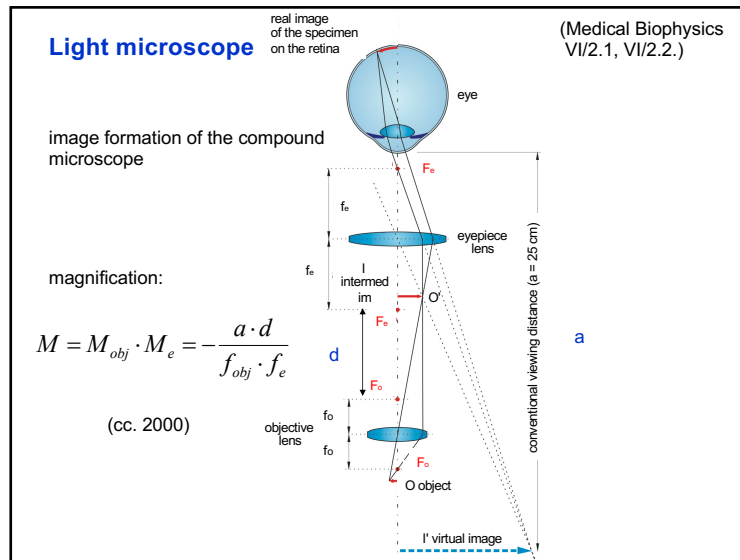


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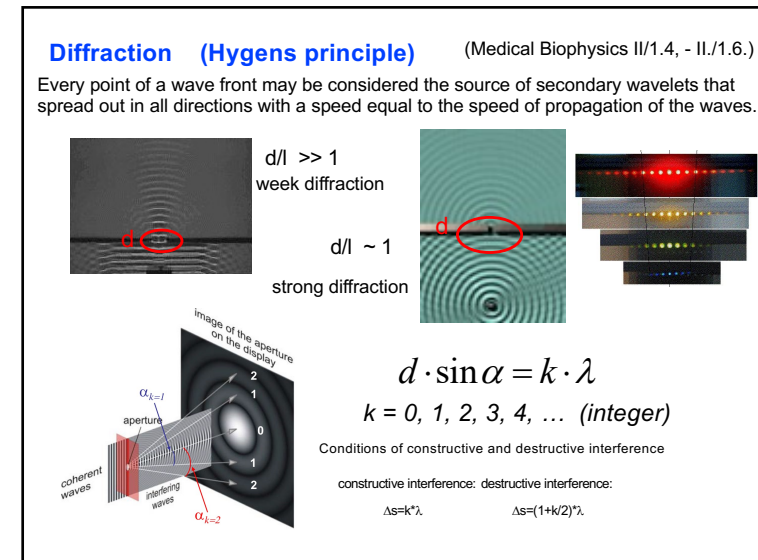
Length scale of structure elements



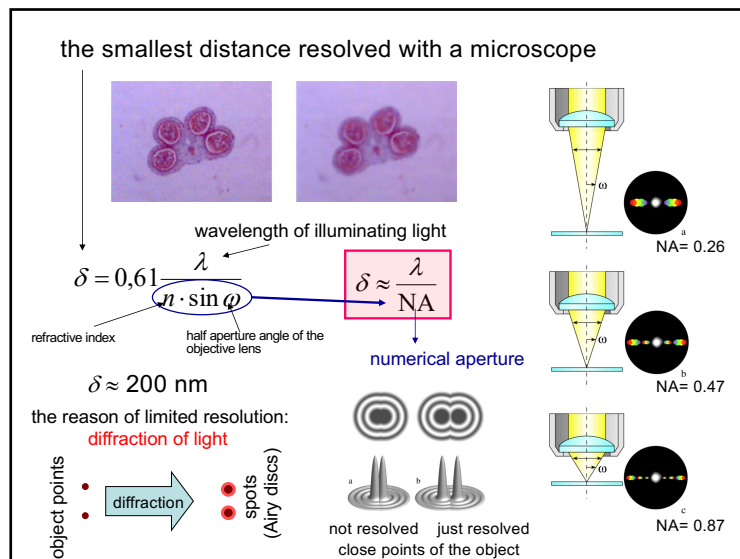
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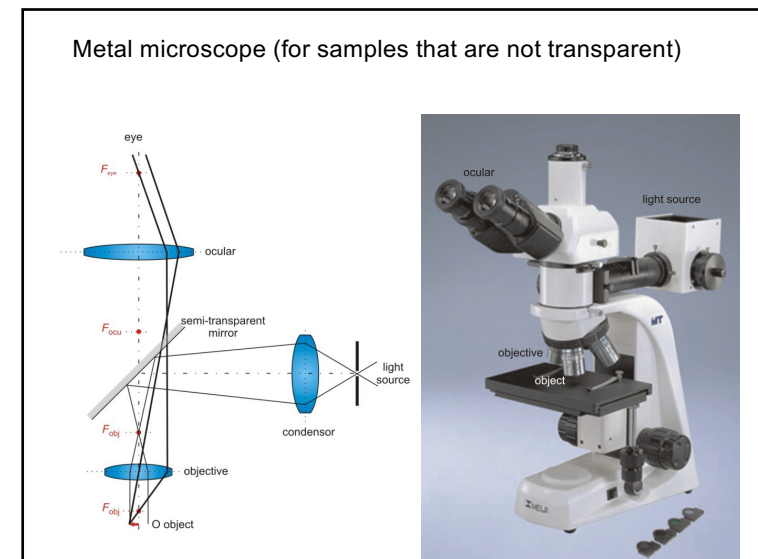
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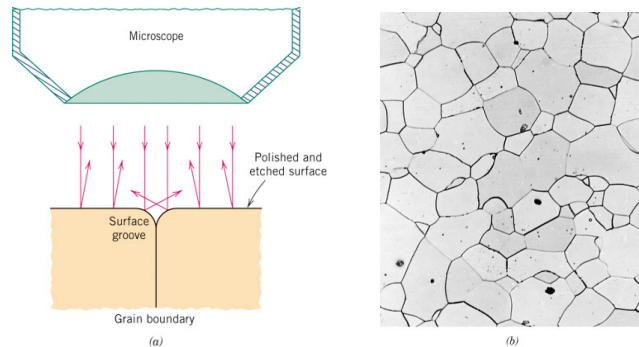


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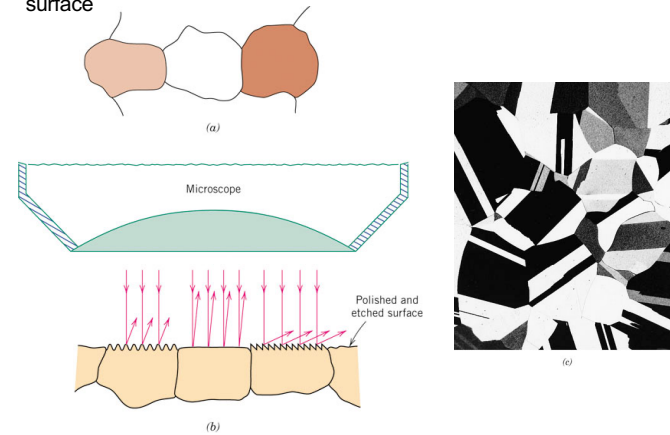
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Image formation of a light microscope from a polished reflecting surface



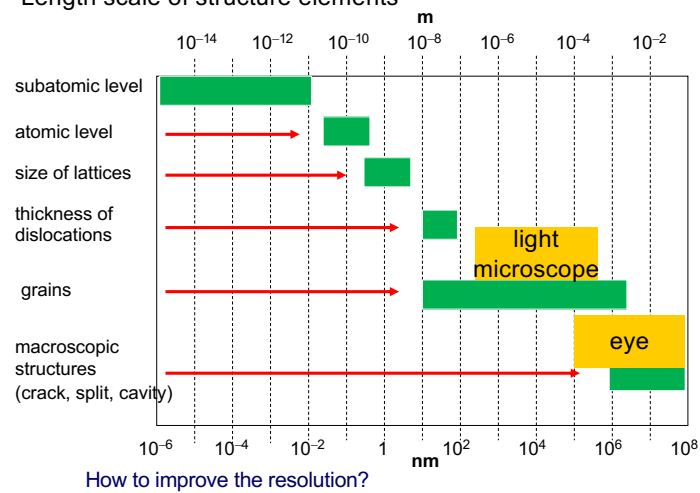
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The microscopic image of a partly polished reflecting surface



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Length scale of structure elements



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Electron microscope

(textbook ch. X/5.)

Theoretical bases of electron microscope

memo: the resolution depends on the wavelength!

$$\delta \approx \frac{\lambda}{NA}$$

Does the electron have wave character?

de Broglie's idea: $\lambda = \frac{h}{m \cdot v} = \frac{h}{p}$

Planck constant (6.63×10^{-34} Js)

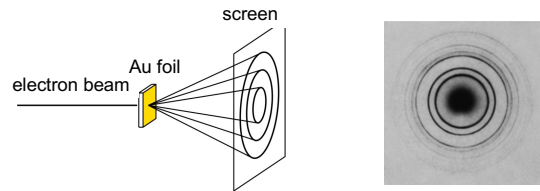
momentum of the electron

The wave nature and a certain wavelength have to be associated to every material mass!

The electron beam should have diffraction!

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Experimental verification: Davisson and Germer (1927)



How small is the limit of resolution?

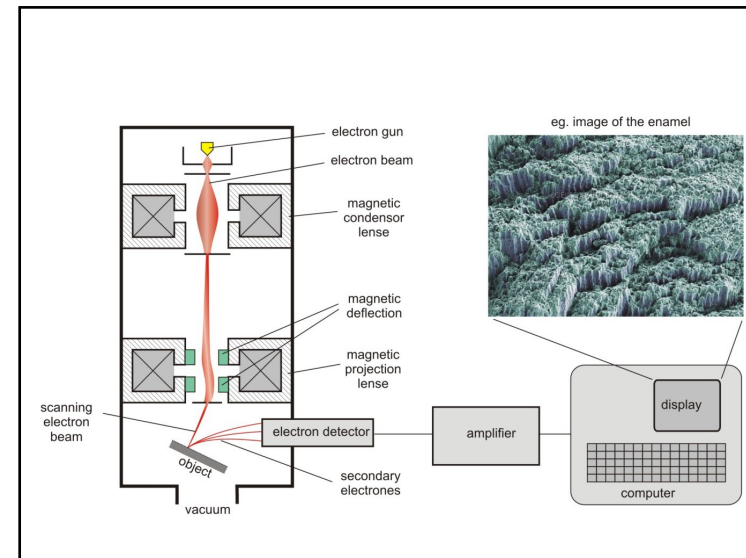
$$\lambda \approx 0,005 \text{ nm} \quad \rightarrow \quad \delta \approx 0,2 \text{ nm}$$

$NA \approx 0,03$

opens up the possibility of imaging sub-cellular details

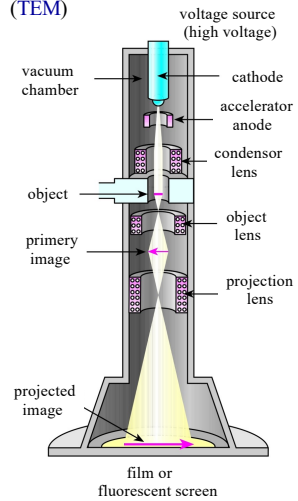
How is it operating?

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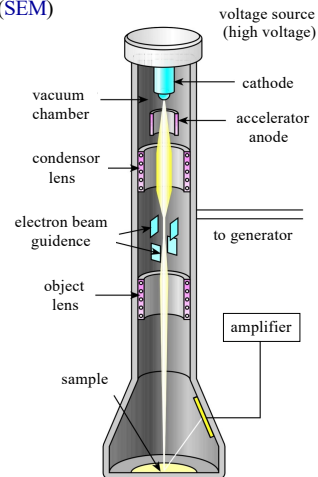


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Transmission electron microscope
(TEM)



Scanning electron microscope
(SEM)



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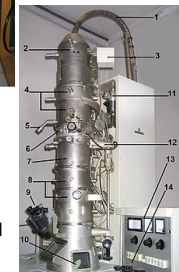
SEM in a Geological Survey



SEM opened sample chamber

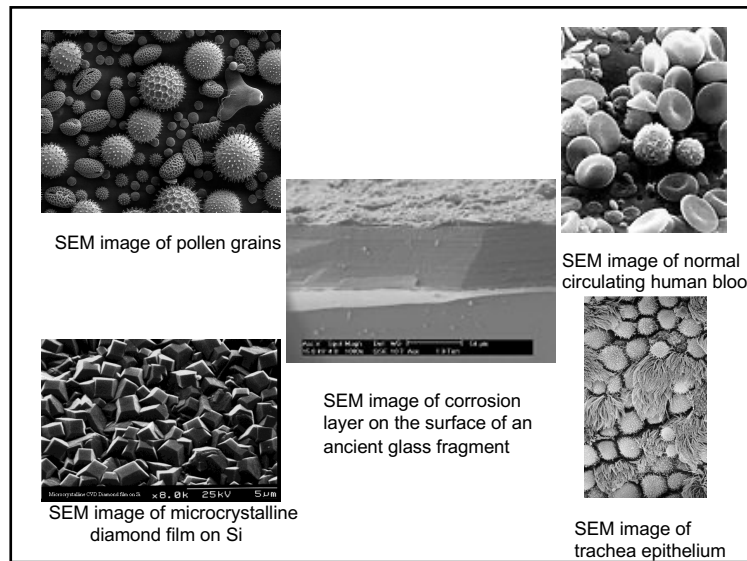


The first TEM
(now on display at
Deutsches Museum
in Munich, Germany)

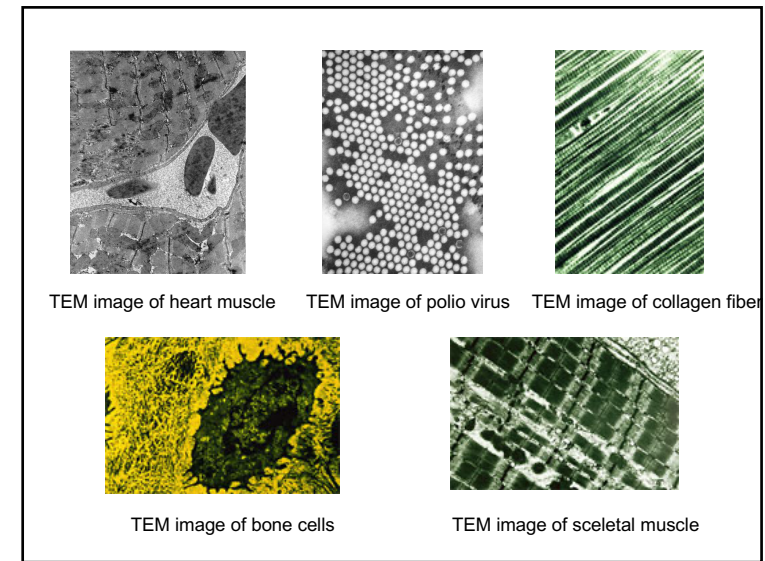


TEM applied
nowdays

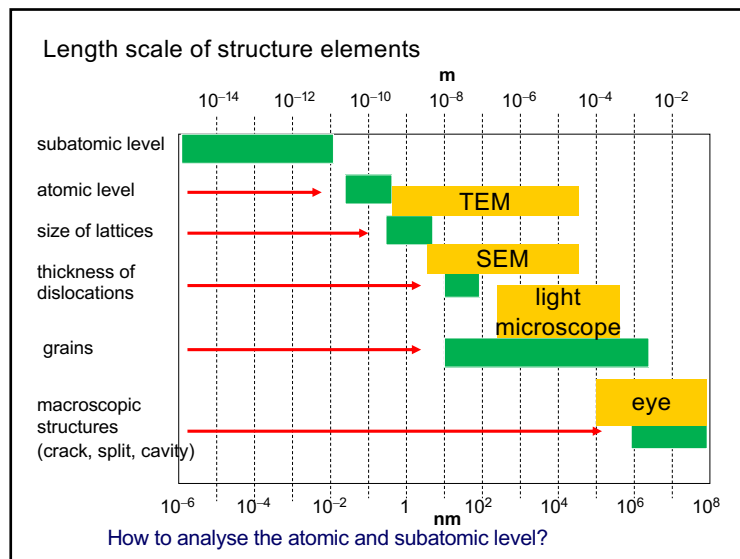
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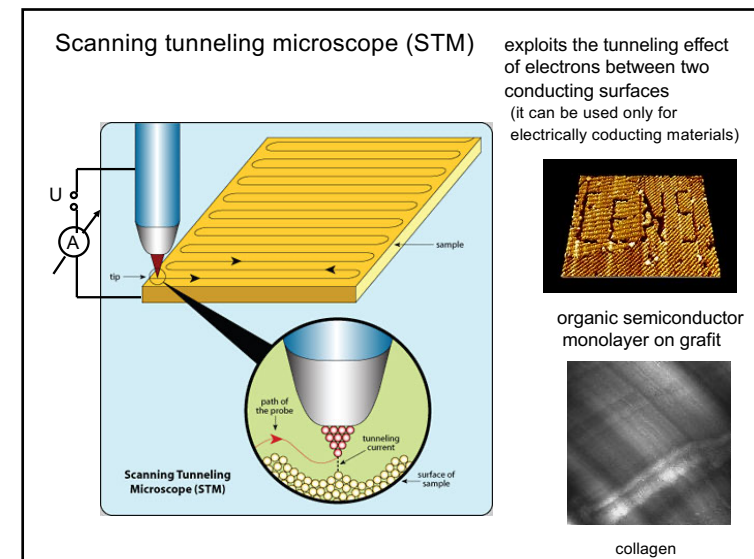
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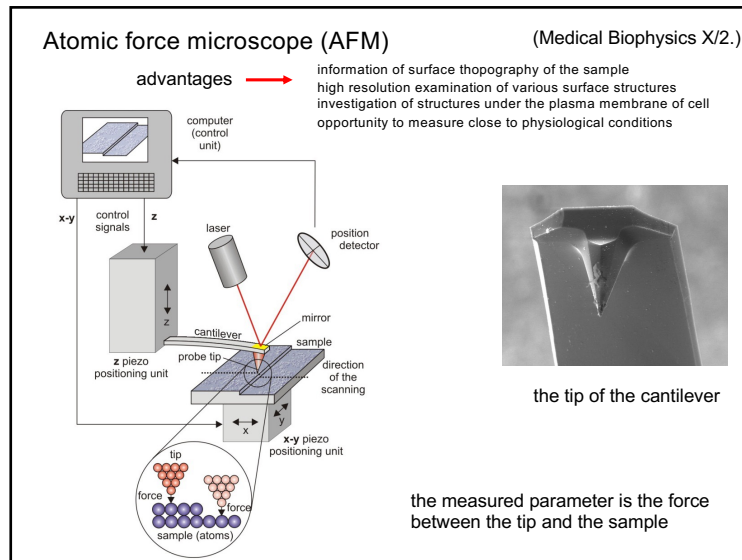
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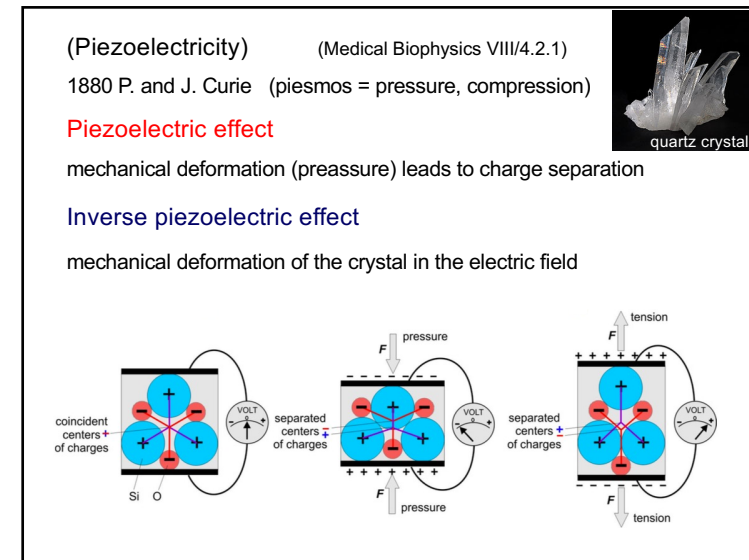
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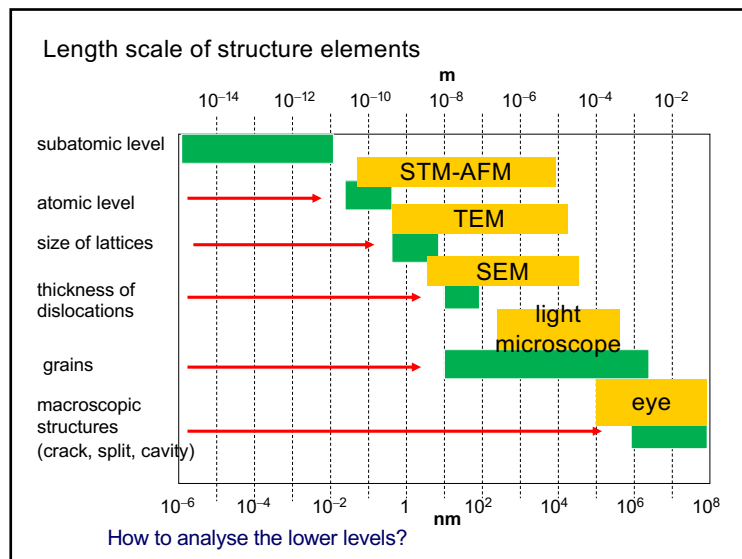
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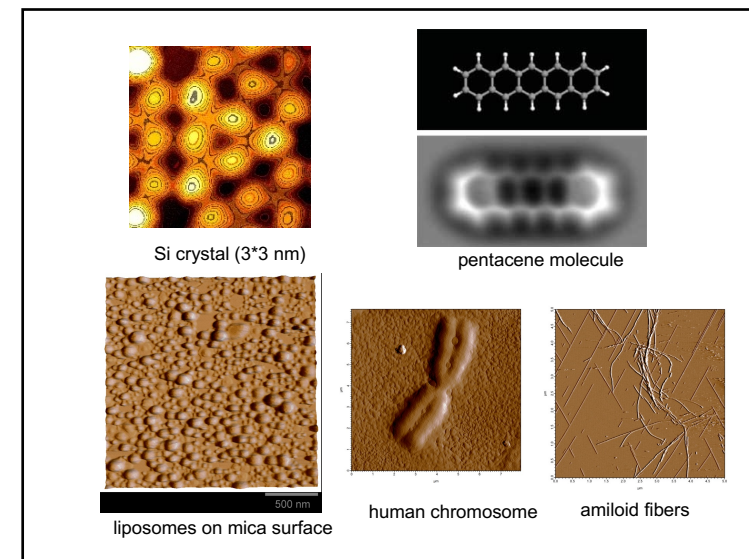
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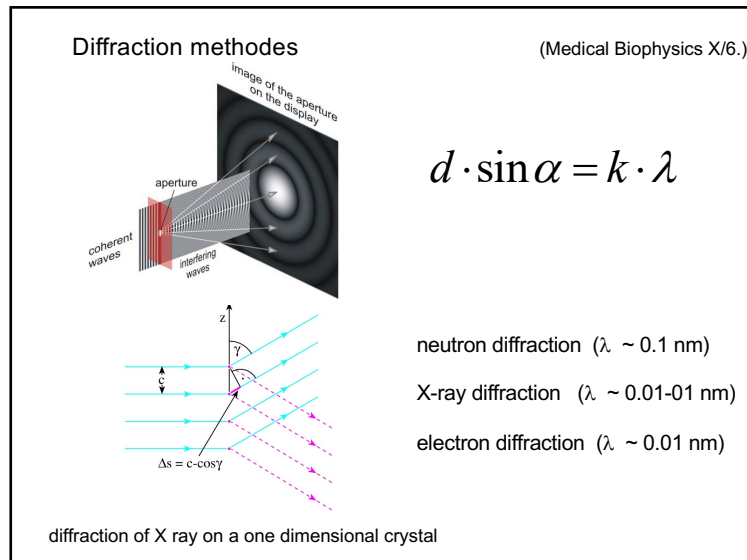
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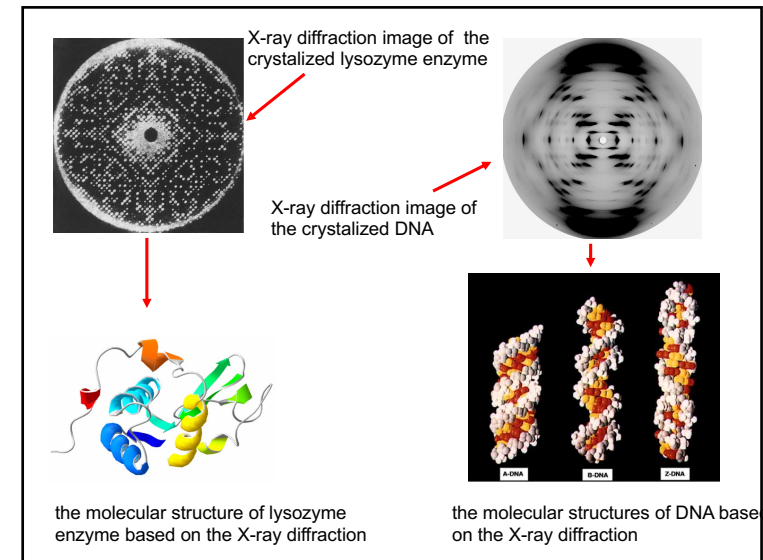
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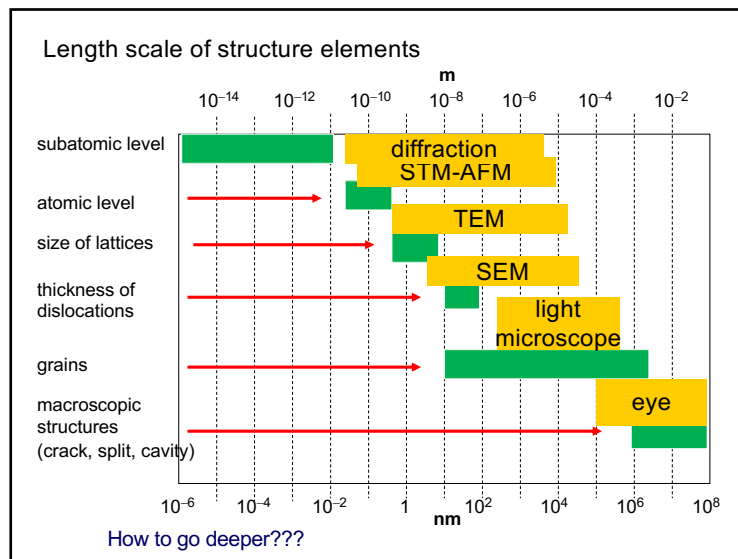
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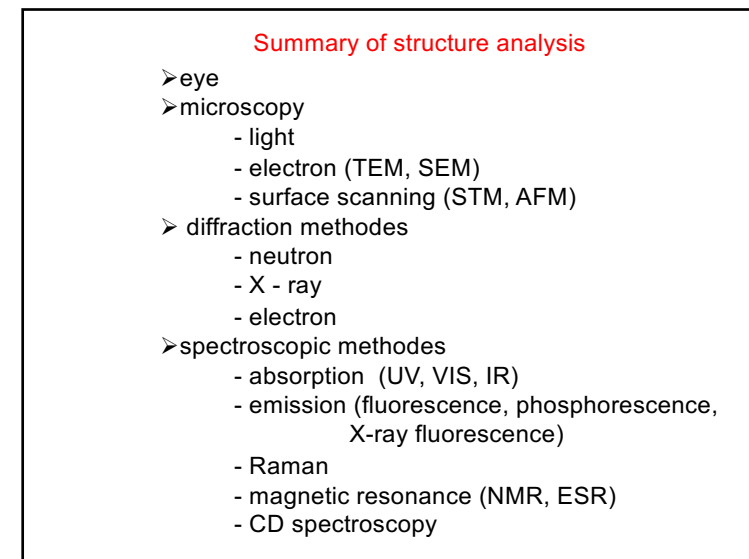
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Calculate the limit of resolution of a microscope, if the wavelength of the illumination light is 515 nm, the half angle of the microscope is 72° ?

$$\delta = 0,61 \frac{\lambda}{n \cdot \sin \omega}$$

$$\delta = 0,61 \frac{515}{1 \cdot \sin 72^\circ} = 330,4 \text{ nm}$$

How will this distance change, if we use a 1,54 refractive index immersion oil instead of the air?

$$\delta = 0,61 \frac{515}{1,54 \cdot \sin 72^\circ} = 214,5 \text{ nm}$$

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Calculate the limit of resolution of an electron microscope, if the wavelength of the electron beam is 0,01 nm, and the numerical aperture of the microscope is 0,02?

$$\delta = \frac{\lambda}{NA} = \frac{0,01}{0,02} = 0,5 \text{ nm}$$

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We examine the gold crystal structure with electron diffraction. The wavelength of the electron beam is 60 pm. The diffraction angle of the first order interference maximum is 8.5° . Calculate the distance between the gold atoms!

$$d = \frac{\lambda}{\sin 8,5} = \frac{60}{\sin 8,5} = 75.1 \text{ pm}$$

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