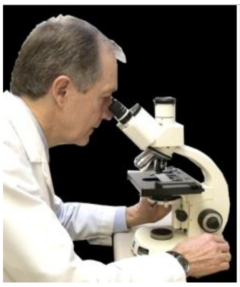
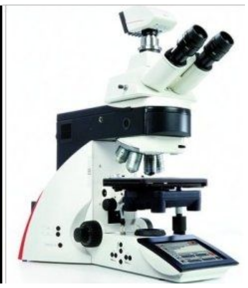
Science

1. Light Microscopes

You know a standard light microscope when you see one. They feature prominently in movies and TV whenever something remotely related to science comes up..

	
Movie scientist with his microscope	**Modern research Microscope (Leica)**.
Rather cheap and rather old standard microscope; only good for looking through thin slices of "biology". The guy pretends. There is no specimen, the light must come from below but is not on, and his hands are on the wrong controls.	That's the kind of routine optical *metallurgical* microscope I use. You cannot look *through* metal specimens, you can only look *at* perfectly flat surfaces. The illumination needs to come from above and there is a camera on top hat records the image. Even top-of-the-line optical microscopes are rather cheap; you get top microscopes for as little as $ 50.000.

Let's go through the three basic ingredients: *probe, detector, information processing* as covered in the introductory module:

- The *probe* is visible light. You may just as well call it electromagnetic waves, moving with the speed of light (3 $\cdot 10^8$ m/s) and with wavelengths from 400 nm - 800 nm.
  Light is generally "sensitive" to materials. *Different* materials reflect light differently - that's why we can see contrast differences in black-and-white. *One and the same* material reflects light with different wavelengths differently - that's why we can see things in color.
- We *detect* the changes that the specimen caused to the probing agency "light" by our eyes. Even today we typically *look* into a microscope. When we take a picture, we use technical sensors like those in a digital camera that convert light intensity and color to an electrical signal, that is processed, appears on a screen, or gets printed. Only if we go for UV or IR microscopy, we use proper sensor arrays right away.
- Our brain does the *image processing*. It knows what it sees from experience and learning, and that includes learning about what you can see in an optical microscope before you turn it on.

There is one big catch to all optical microscopes: The resolution you select by adjusting optical lenses and apertures, also gives you the **depth of focus**. If you go all out with a light microscope and crank up the resolution to 1 µm or even somewhat better, your depth of focus is also roughly one micrometer. That means that anything more than a few micrometers above or below the plane you focus on, will be just blurred and not visible.

The immediate consequence is that the specimen needs to be rather flat and, if you go for transmission, rather thin. If we forget about looking *through* the specimen since this is not practical for iron for obvious reasons, we only discuss surface microscopy here.
To the unaided eye a flat enough surface looks polished to a high sheen. Polishing a surface to a high sheen might be tricky and labor intensive (e.g. if you do it the old-fashioned way for a Japanese sword) but is not a real problem. The real problem is that on a perfectly flat surface there is nothing left to see. So you must do something to your polished specimen that brings out some structures on a micrometer level that you can see.

That is often the really difficult procedure and bordering the "black arts". In some special modules you find a few hints about how it is done for steel or silicon.

- How good is your brain as image processor? How do you *know* what you see in a microscope? After all, you only see things that you have never seen before with your own eyes.
  - Actually, your brain is not very good. It does not know offhand what your eyes see and pass on for processing. It just can sort the things rendered visible into categories like black, white or red, longish, irregular, round, and so on. This it can do very well. What those things *mean* your brain can't know most of the time (in contrast to mine). You must upload some software that enables the brain to recognize that those zebra patterns actually signify the presence of pearlite in steel, for example. Unfortunately, the uploading process, also known as learning /studying, takes many years.
    Just look at any of the microscope pictures coming up in the Hyperscript (here is an example) but do not read the figure captions. Do you know what you see? No, you don't. You need additional information from other sources to know what you see. That is true for light microscopes and especially true for transmission electron microscopes.

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