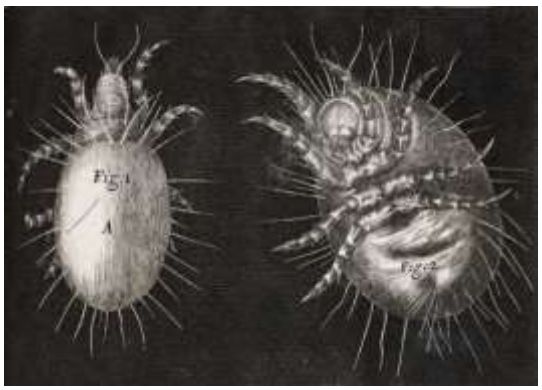
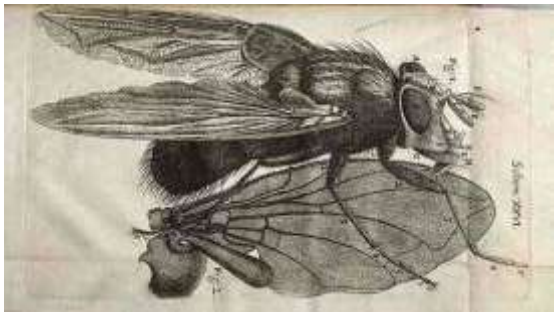
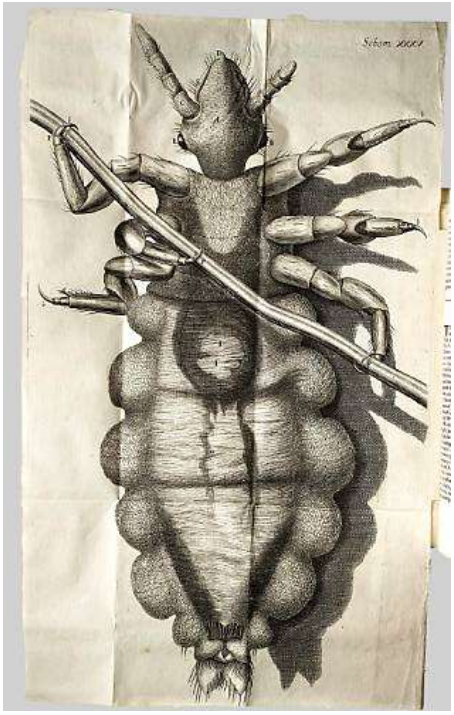
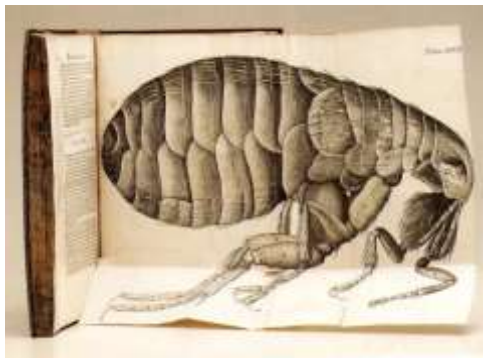
Seeing the Invisible: Using the Properties of Light and Pigments to Make Microscopic Organisms, including Germs, Visible

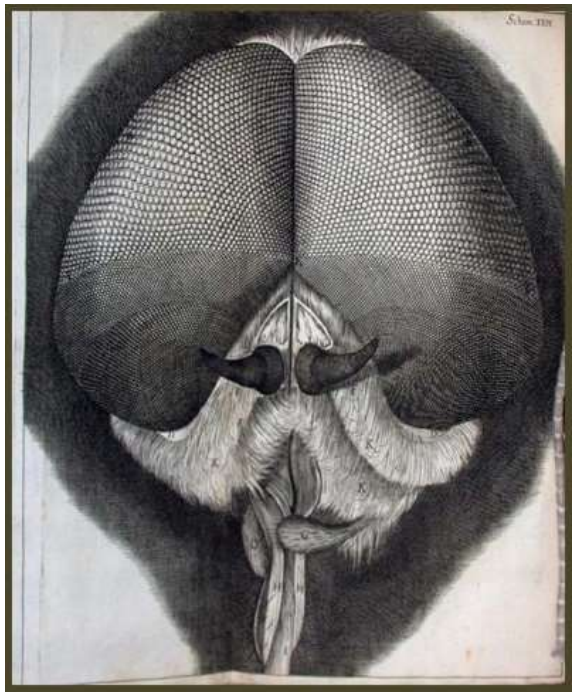
In 1665, **Robert Hooke** published a stunning book entitled, ***Micrographia****: or Some Physiological Descriptions of Minute Bodies Made by Magnifying Glasses with Observations and Inquiries thereupon* that was illustrated with engravings of the objects he saw with his microscope. He saw the cells that composed cork, and the hairs of a blue fly, a flea, mites, a louse and stinging nettle.



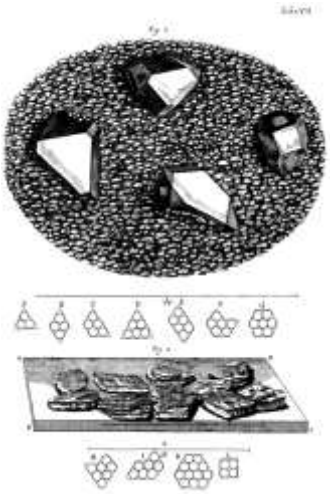




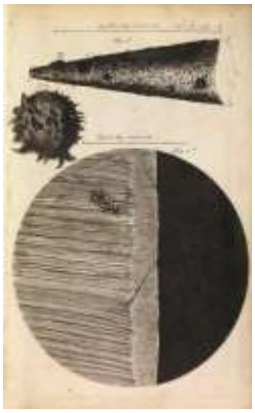




Robert Hooke also observed shards of flint, crystals in urine, and the eye of a grey drone-fly with his microscope. He saw beauty in works of nature; and the microscope revealed to him that "*the deepest discoveries shew us the greatest excellencies. An evident argument, that he that was the author of all these things, was no other than omnipotent; being able to include as great a variety of parts and contrivances in the yet smallest discernable point, as in those vaster bodies (which comparatively are also called points) such as the earth, sun, or planets*."



Robert Hooke came to these conclusions about the author of all things after comparing the form of nature's lowest accomplishments with man's finest technological accomplishments, such as the point of a needle or the edge of a razor, where "*the more we see of their shape, the less appearance will there be of their beauty*."



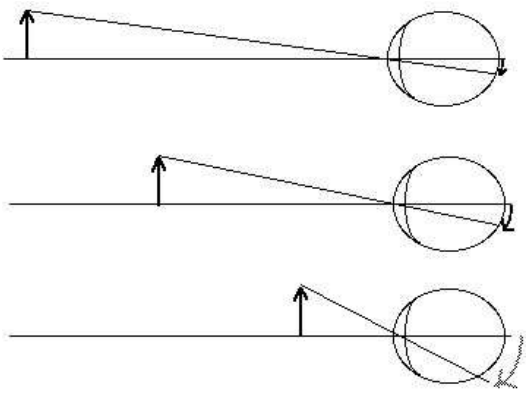
Robert Hooke intended to share his newly discovered world with anyone who was interested and the ***Micrographia*** became the first scientific bestseller—even though it was expensive, selling at a price of 30 shillings. Robert Hooke wrote in the preface, "*by the means of* ***telescopes****, there is nothing so far distant but may be represented to our view; and by the* ***microscopes****, there is nothing so small, as to escape our inquiry; hence there is a new visible world discovered to the understanding. By this means the heavens are open'd, and a vast number of new stars, and new motions, and new productions appear in them, to which all the ancient astronomers were utterly strangers. By this the earth it self, which lyes so neer us, under our feet, shews quite a new thing to us, and in every little particle of its matter, we now behold almost as great*

a variety of creatures, as we were able before to reckon up in the whole universe it self…. I here present to the world my imperfect indeavours' which though they shall prove no other way considerable, yet, I hope, they may be in some measure useful to the main design of a reformation in philosophy, if it be only by shewing, that there is not so much requir'd towards it, any strength of imagination, or exactness of method, or depth of contemplation (though the addition of these, where they can be had must needs produce a much more perfect composure) as a sincere hand, and a ***faithful eye****,* ***to examine****, and to record, the things themselves as they appear*."

In inviting us to travel through the newly discovered microscopic world, Robert Hooke gives us some advice: "*The truth is, the science of nature has been already too long made only of work of the brain and the fancy: It is now high time that is should return to the plainness and foundations of observations on material and obvious things.* ***It is said of great empires, that the best way to preserve them from decay, is to bring them back to the first principles, and arts, on which they did begin. The same is undoubtedly true in philosophy, that by wandring far away into invisible notions, has almost quite destroy'd it self, and it can never be recovered, or continued, but by returning into the same sensible paths, in which it did at first succeed…..true philosophy…is to begin with the hands and eyes, and to proceed on through the memory, to be continued by the reason; nor is it to stop there, but to come about to the hands and eyes again….*"

The microscope facilitates our journey into the microscopic world because it can **resolve two points separated by a distance that is smaller than the wavelength of visible light (400-700 nm).** By contrast, the human eye is only able to resolve two separate points that are greater than **70,000 nm** or 0.07 mm from each other. This is equivalent to one minute of arc. The **acuity** of the human eye is limited by the diameters of the **cones**, which are about 2 μm, in the **fovea** of the **retina**. The **cornea** and **crystalline lens** act together as a **converging lens** that produces a real minified inverted image of the object on the retina.

If light from two nearby points on an object fall on the same cone, the two points will appear to **our mind's eye** as one. If light from the two points fall on two separate cones separated by a third cone, the two points will be clearly resolved. The resolving power of the eye can be increased slightly by eye movements that vary the position of the cones.



In order for two points to appear as separate points, light from those points must enter the eye forming an angle greater than one minute of arc. This can be done by bringing the object very close to the eye. However, due to the limitation of our eye to focus at close distances, a specimen can be brought up only to the **near point of the eye**, which is about 25 cm from our eye. A microscope is a compound magnifying glass that makes it possible to increase the visual angle, so that light, emanating from two near but separate points, can enter the eye, forming an angle that subtends more than one minute of arc such that the light from the two separate points fall on separate cones.

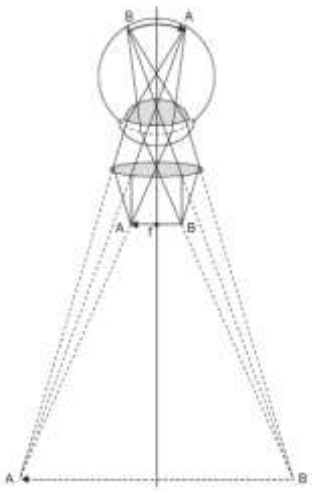
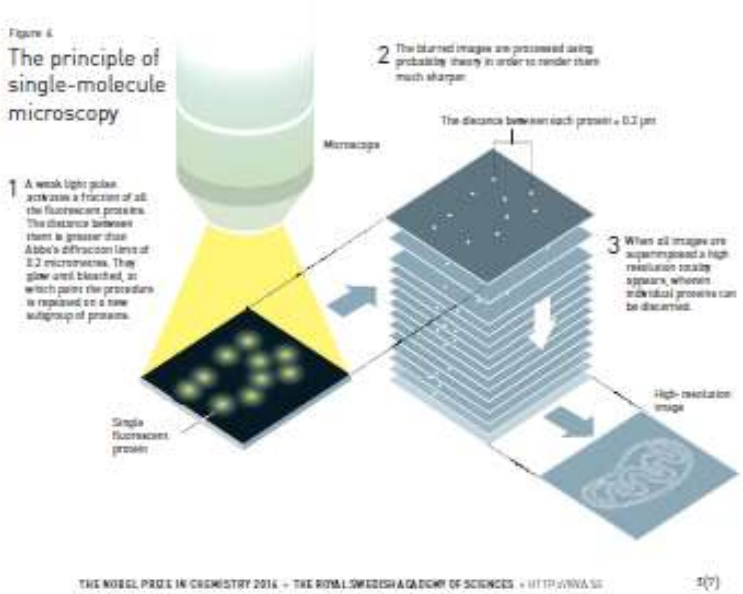
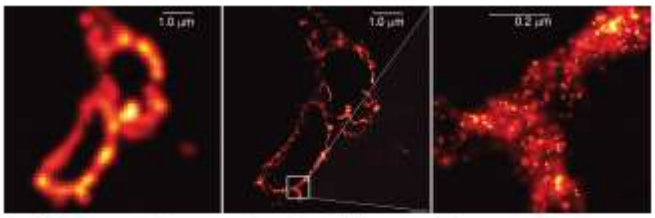


FIGURE 4.1 A simple microscope placed in front of the eye increases the visual angle, thus producing an enlarged image of a microscopic specimen on the retina. The specimen appears to be located at the near point of the relaxed eye and magnified.

The 2014 Nobel Prize in Chemistry was awarded to Eric Betzig, Stefan Hell and William Moerner "*for the development of super-resolved fluorescence microscopy*" that can image individual molecules. They turned **microscopes** into **nanoscopes**!

http://www.nobelprize.org/nobel_prizes/chemistry/laureates/2014/popular-chemistryprize2014.pdf





Neil deGrasse Tyson (2009) lamented the limitations of the eye in *The Perimeter of Ignorance*: "*The eye is often held up as a marvel of biological engineering. To the astrophysicist, though,* ***it's only a soso detector****. A better one would be much more sensitive to dark things in the sky, and to all the invisible parts of the spectrum. How much more breathtaking sunsets would be if we could see ultraviolet and infrared. How useful it would be if, at a glance, we could see every source of microwaves' in the environment, or know which radio station transmitters were active. How helpful it would be if we could spot police radar detectors at night*."

On the other hand in *An Essay Concerning Human Understanding*, **John Locke** (1690) indicated that we might be fortunate to have eyes with limited acuity. John Locke (1690) wrote, "*We are able, by our senses, to know and distinguish things....if that most instructive of our senses, seeing, were in any man a thousand or a hundred thousand times more acute than it is by the best microscope, things several millions of times less than the smallest object of his sight now would then be visible to his naked eyes, and so he would come nearer to the discovery of the texture and motion of the minute parts of corporeal things; and in many of them, probably get ideas of their internal constitutions: but then he would be in a quite different world from other people: nothing would appear the same to him and others: the visible ideas of everything would be different. So that I doubt, whether he and the rest of men could discourse concerning the objects of sight, or have any communication about colours, their appearances being so wholly different. And perhaps such a quickness and tenderness of sight could not endure bright sunshine, or so much as open daylight;*

nor take in but a very small part of any object at once, and that too only at a very near distance. And if by the help of such microscopical eyes (if I may so call them) a man could penetrate further than ordinary into the secret composition and radical texture of bodies, he would not make any great advantage by the change, if such an acute sight would not serve to conduct him to the market and exchange; if he could not see things he was to avoid, at a convenient distance; nor distinguish things he had to do with by those sensible qualities others do. He that was sharp-sighted enough to see the configuration of the minute particles of the spring of a clock, and observe upon what peculiar structure and impulse its elastic motion depends, would no doubt discover something very admirable: but if eyes so framed could not view at once the hand, and the characters of the hour-plate, and thereby at a distance see what o'clock it was, their owner could not be much benefited by that acuteness; which, whilst it discovered the secret contrivance of the parts of the machine, made him lose its use."

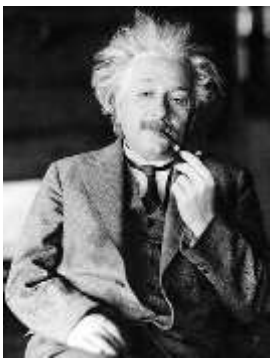
In *An Essay on Man*, **Alexander Pope** (1745) considered the same question:

Why has not Man a microscopic eye?
For this plain reason, Man is not a Fly.
Say what the use, were finer optics given,
T'inspect a mite, not comprehend the heaven.

Given the limitations of the human eye, microscopes are necessary to see the invisible in the microscopic world. **Augustus de Morgan** (1872), the mathematician, wrote this couplet about the microscopic world seen by the seventeenth and eighteenth century microscopists.

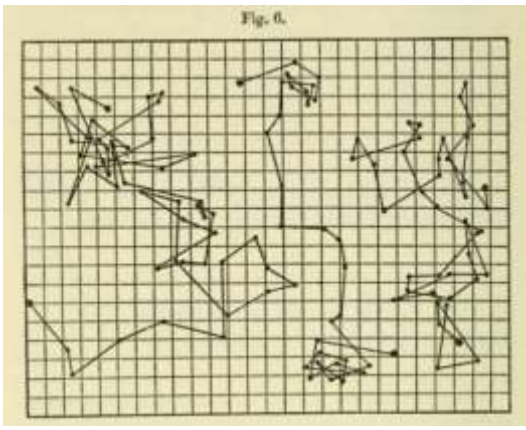
Great fleas have little fleas upon their backs to bite e'm,
And little fleas have lesser fleas, and so on ad infinitum.

The word microscope, which was coined by Giovanni Faber on April 13, 1625, comes from the Greek words *mikrós μικρός* and *skopeîn σκοπεῖν*, which mean "small" and "to see." Microscopes, known as **flea glasses**, for obvious reasons, were used for decades before Hooke made his observations. The bright-field microscope is, perhaps, one of the most elegant instruments ever invented, and the first microscopists used the technologically advanced increase in the resolving power of the human eye to reveal that the workmanship of the Creator can be seen at the most minute dimensions. The bright-field microscope made it possible to reveal the cell as the basic unit of life in the early 17th century, the structural basis for the transmission of inherited characteristics and the microscopic basis of infectious diseases in the late 19th century, and the reality of molecules in the 20th century.



While studying pollination in plants, **Robert Brown** (1828, 1829) serendipitously discovered the incessant movement of living and nonliving particles, now known as **Brownian motion** with his simple botanical bright-field microscope. In 1905, **Albert Einstein** analyzed Brownian motion and concluded that the movement occurred as a result of the statistical distribution of forces exerted by the water molecules surrounding the particles. **Jean Perrin** (1909) confirmed Einstein's hypothesis by observing Brownian motion under the microscope and used his observations, along with Einstein's theory, to calculate Avogadro's number, the number of molecules in a mole. Ernst

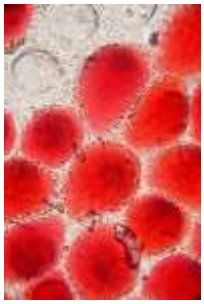
Mach and Wilhelm Ostwald, who were the last holdouts to accept the **reality of atoms and molecules**, became convinced in the reality of molecules from the work done on Brownian motion. These influential scientists were held back from accepting the evidence of the existence of molecules from other kinds of physicochemical data because of their **positivist philosophy**, which could be summed up by the phrase "seeing is believing."



Demonstration: Carefully use the replica of **Leeuwenhoek's microscope** to see the hairs on the wing of a house fly. This is a simple microscope; meaning that it only has one converging lens that produces a virtual, magnified, erect image of the specimen. If the light source or better yet for this microscope, the sun is directly behind the specimen, you will have bright-field illumination, is the light source is perpendicular to the specimen, you will have dark-field illumination and if the light source is at a forty-five degree angle to the specimen, you will have oblique illumination. Each type of illumination produces a different kind of image.

The bright-field microscope provides the best contrast when viewing **colored objects**. Plant cells can be naturally colored with anthocyanins, carotenoids and chlorophyll. Cells also can be colored with natural and artificial dyes.

Demonstration: Put a thin piece of a **flower petal** on a drop of water on a glass slide. The cells of the petals are colored with **anthocyanins**. The red anthocyanins attract hummingbirds, sunbirds and butterflies that have a long-



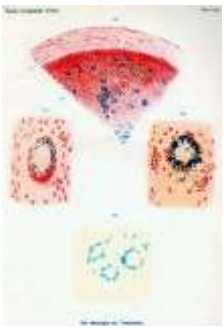
wavelength photopsin in their retina and are sensitive to red light.

Natural dyes used to color fabrics were employed by **John Hill** (1770) to demonstrate the path that water took through the stem of the tree. By adding the **cochineal dye**, John Hill saw that "*the course of the vessels, is very distinctly and beautifully seen by it; for they only are crimson*." This was most likely the first use of dyes to selectively stain tissues. As we will discuss next week, cochineal is the dye that had been used to color the robes of **Catholic Cardinals** and the dye that would be used to color the uniforms of the British officers during the Revolutionary War giving them the name, **redcoats**. **Dyes became very important for elucidating the germ theory of disease**.

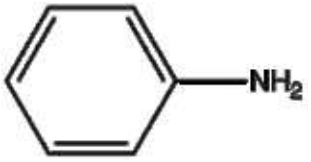
The microscope made it possible to discover invisible living organisms such as bacteria that can cause **disease**. Antony van Leeuwenhoek (1684) discovered bacteria living between his teeth: "*Tho my teeth are kept usually very clean, nevertheless when I view them in a magnifying glass, I find growing between them a little white matter as thick as wetted flower: in this substance tho I could not perceive any motion, I judged there might probably be living creatures. I therefore took some of the flower and mixt it either with pure rain water wherin were no animals; or else with some of my spittle (having no air bubbles to cause motion in it) and then to my great surprise perceived that the aforesaid matter contained very* ***many small living animals****, which moved themselves very extravagantly.*

The biggest sort had the shape of A. their motion was strong and nimble, and they darted themselves thro the water or spittle, as a Jack or Pike does thro the water."

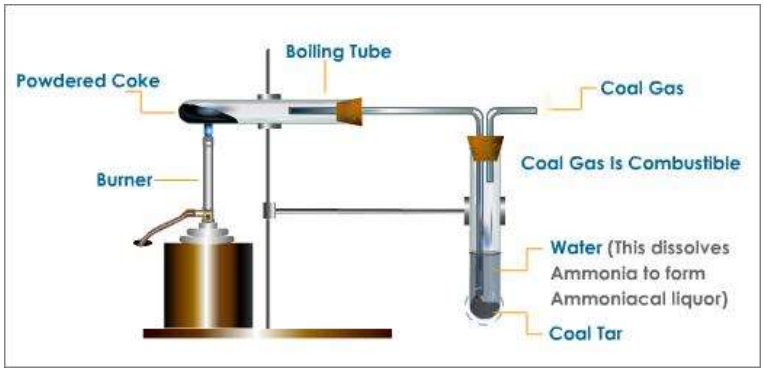
Alexander Gordon (1795), Oliver Wendell Holmes Sr. (1843), **Ignaz Semmelweis** (1844) and Louis Pasteur (1856) among others proposed that diseases, such as puerperal fever or **childbed fever,** were caused by **germs** that had been transferred from the cadavers upon which autopsies were performed to the pregnant women who were delivering. Unbelievably, the doctors actually delivered babies without washing their hands after they performed autopsies. However, it was the consensus of the medical profession that the germ theory of disease was just silly; one obstetrician saying, "*Doctors are gentlemen, and gentlemen's hands are clean*." The medical profession, with its consensus, was wrong. **Kurt Vonnegut** (1981), a Cornellian, tells about this time in history in a commencement address he gave to the graduating class of Southampton College. He told them: "***My hero is Ignaz Semmelweis. I will go on to recommend to those graduating from colleges everywhere in the world this spring that their hero be Ignaz Semmelweis.****"* I have appended an excerpt of Kurt Vonnegut's speech to these lecture notes and you can find the entire speech here (http://www.nytimes.com/books/97/09/28/lifetimes/vonnegut-commencement.html).

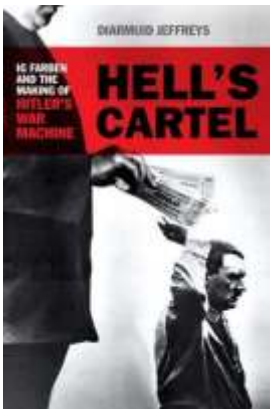


It became **Robert Koch's** (1877) job to prove beyond a shadow of a doubt that bacteria were the cause of many diseases, including **tuberculosis** and **anthrax**. The first thing Robert Koch had to do was to develop staining procedures that would allow the bacteria to be visualized in blood smears and in tissues. Robert Koch made use of the new **aniline dyes**, including methyl violet, fuschin and aniline brown



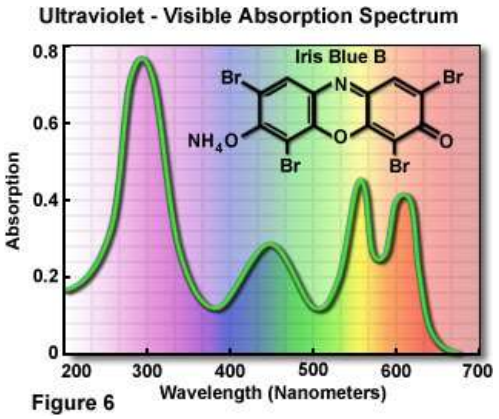
developed by the **German dye industry** to **stain the bacteria**. As we will discuss next week, the aniline dyes were produced from **coal tar**, the residue from the production of **coal gas** used for street lighting. The companies, including Agfa, BASF, Bayer and Hoechst that produced the aniline dyes became part of **I. G. Farben** that built the concentration camp at **Auschwitz** where prisoners made rubber from coal.





Paul Ehrlich (1878) further developed the technique of **biological staining** using the **aniline dyes**. Paul Ehrlich was interested in combining chemistry and histology to study human cells and wrote a thesis entitled, *Chemical and Histological Staining Principles Using Aniline Dyes*. After hearing Robert Koch speak about germs, Paul Ehrlich noticed that some **dyes selectively bound to germs** but not to the cells they infected. Paul Ehrlich then realized that it would be possible to find a drug that directly targeted the germ (parasitotropic) without targeting the human host cells (organotropic). Such a drug would act as a **magic bullet** against germs. Paul Ehrlich's first success in **chemotherapy**, a word he coined, was **Salvarsan**—the arsenic that saves. Salvarsan cured syphilis by selectively targeting the spirochete that caused it. Seeing more than the light coming through the eyepieces of his microscope, Paul Ehrlich founded the life-saving field of chemotherapy.

Dyes are chemicals with several **conjugated double bonds** that absorb certain regions of the spectrum and reflect or transmit others. They only bind to the parts of the specimen that have certain chemical characteristics, particularly in terms of charge. When the specimen is illuminated with white light, the **amplitudes of the waves** with wavelengths that are absorbed by the dye are diminished. The amplitudes of the waves with wavelengths that are not absorbed by the dye pass through unchanged, resulting in a **differentially-colored specimen**. The reduction of the amplitude of a wave when light passes through a dye is equivalent to the absorption of photons by the dye.



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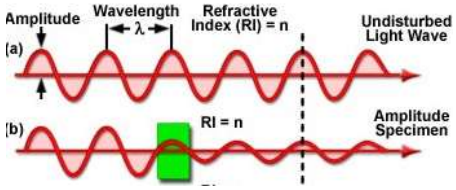
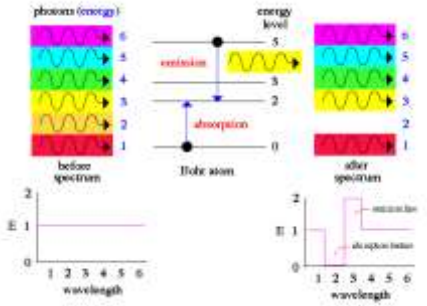
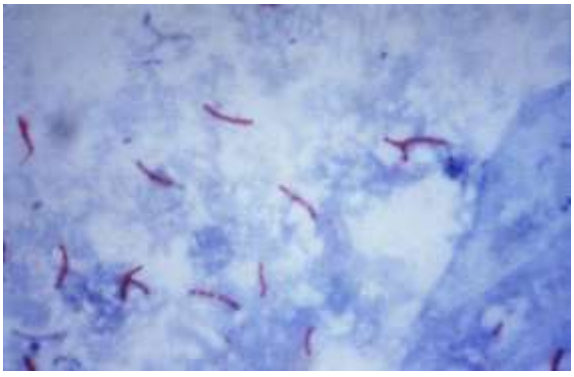
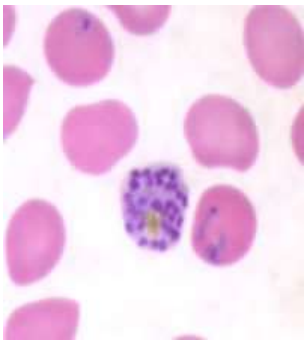
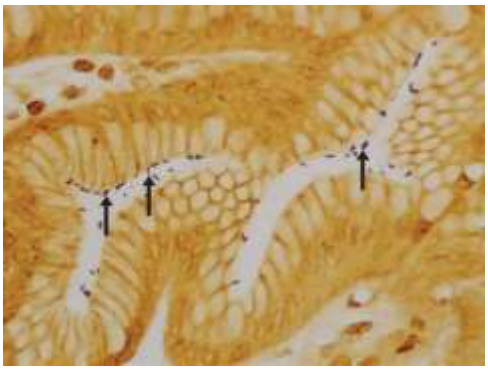




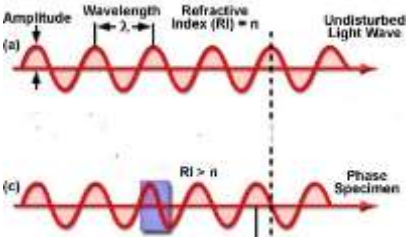
Better stains and specific staining methods allows the identification of specific disease-causing germs so that the diseases can be identified. The Ziehl-Neelsen stain colors the tuberculosis bacterium red, Giemsa stain colors malaria parasite blue, and the Warthin-Starry stain colors *Helicobacter pylori* black.

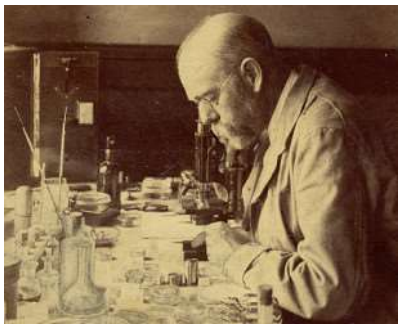


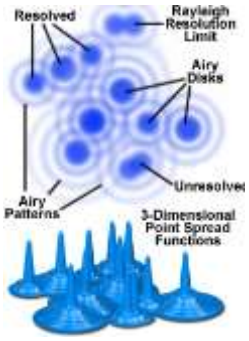


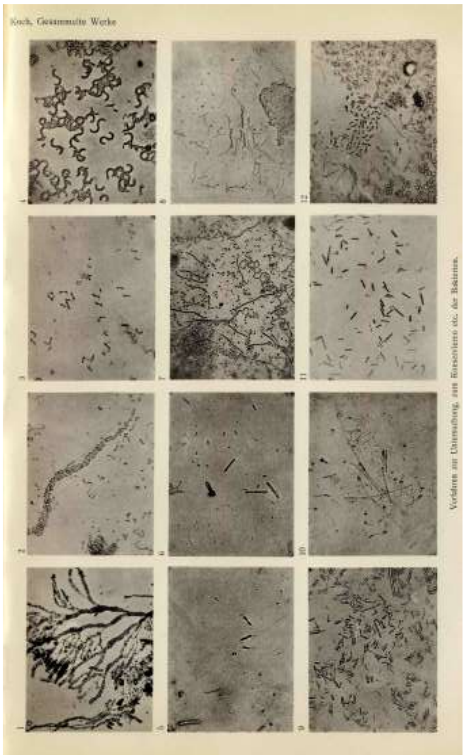


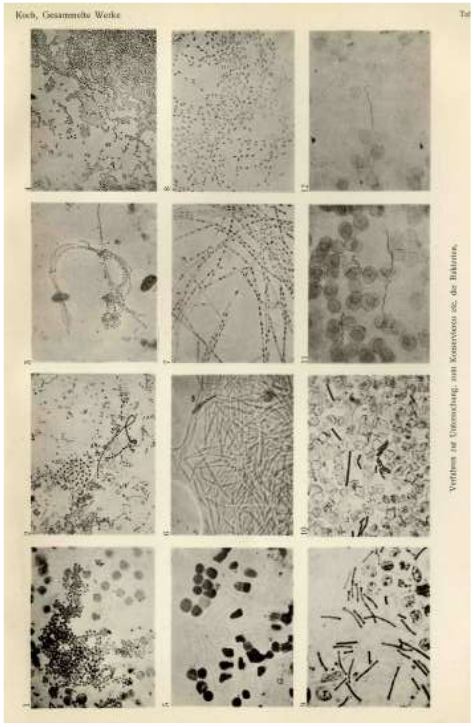
Thomas Young predicted that an understanding of the interference of waves caused by small objects would be important for microscopists in order to know **which parts of the image were actually parts of the object** and which ones were introduced by the **wave nature of light**. Contrast in transparent objects that introduce a change in the phases of the light waves result from destructive and constructive interference of the light waves. The trick is to know which dark and bright spots are true to the object and which are unfaithful. **Robert Koch** (1877) realized that when bacteria were observed with axial light, they seemed to have a capsule around them and realized that the capsule did not exist in the object itself but resulted from the **dark and light rings caused by diffraction**. He could eliminate this diffraction artifact by illuminating the object with a wide cone of light.



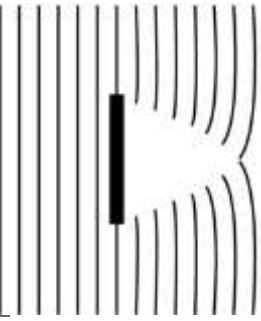






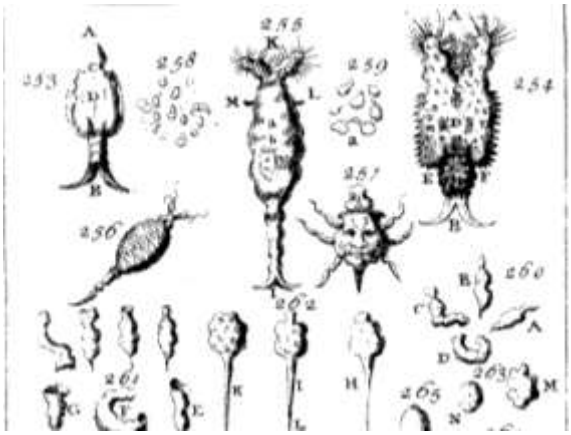


Demonstration: Repeat the experiment performed successfully by Thomas Young and unsuccessfully by Isaac Newton. Illuminate a slip of card using axial laser light and observe the image. Notice

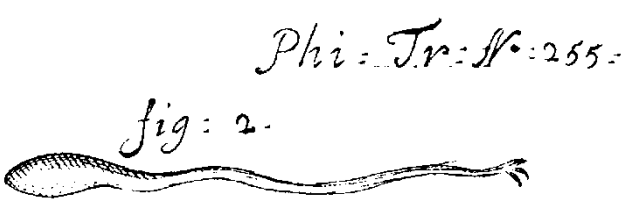


how the light bends behind the card and produces an image that is ***not*** a faithful representation of the object. This is a result of **diffraction produced by the wave nature of light**. This demonstration requires axial light. Perhaps Isaac Newton missed seeing this result because he performed the experiment on a day when the sun's rays were too diffuse.

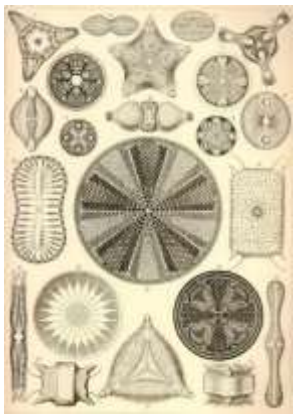
A lack of knowledge of the wave nature of light and the unfaithful images it may produce probably explains the observation of the **homunculus** by Nicolas Hartsoeker (1694) and of the **human-looking animalicule** (#257) by George Adams (1747).

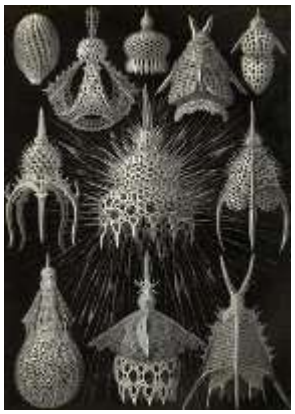


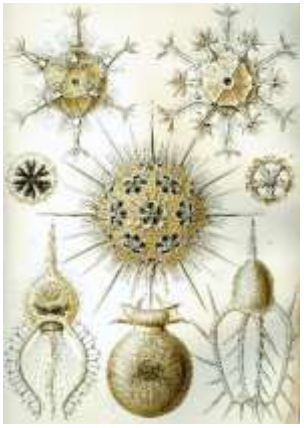
Even **Antony van Leeuwenhoek** (1699) could see something that may not have been there: *"I have in fact imagined that I could say as I beheld the animalcules in the semen of an animal that there lies the head and there as well the shoulders and there the hips; but since these notions have not the slightest shred of certainty,* ***I will not yet put forward such a claim, but hope that we may have the good fortune to find an animal whose male seed will be so large that we will recognize within it the figure of the creature from which it came****."*



I want to give a short aside on Ernst Haeckel. **Poets** and **painters** have always been able to share the beauty of the natural world with others. Like Robert Hooke, **Ernst Haeckel** (1899-1904) wanted to share the beauty of the natural world that was invisible to most people but visible to him. He published a series of books entitled, ***Art Forms in Nature***, so that he could share with others the world that was made visible with the microscope. Haeckel also shared his







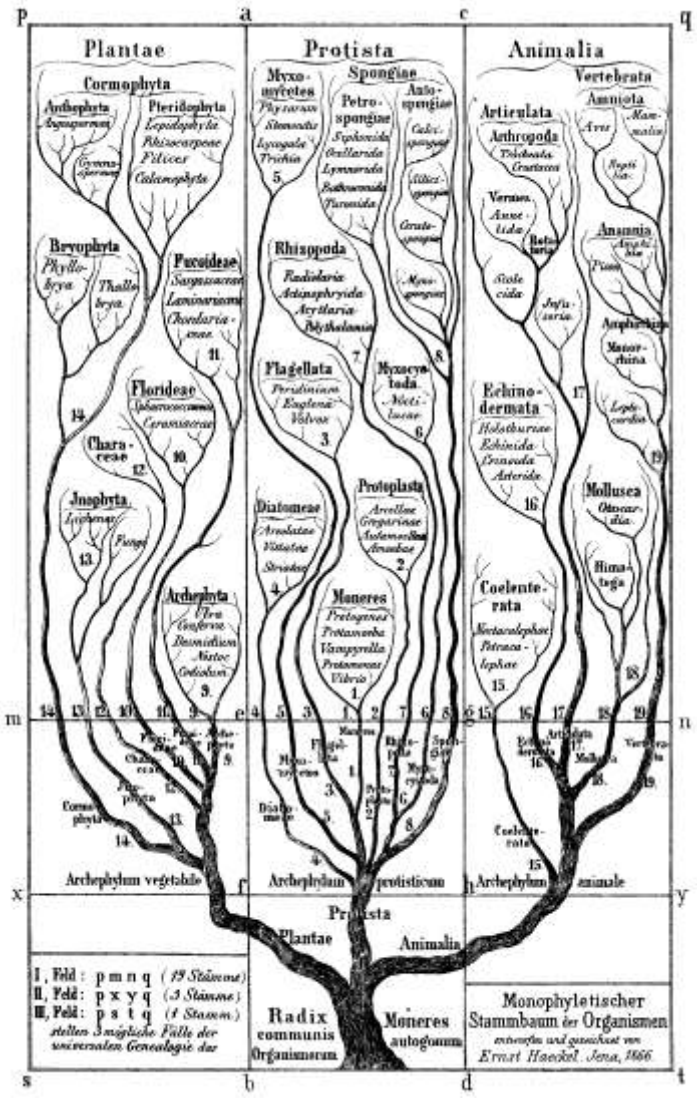
vision of the **color and form** of larger organisms that we have discussed this semester.



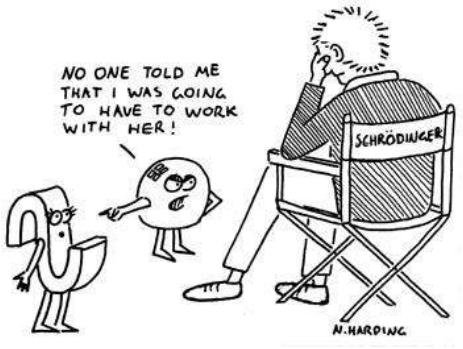


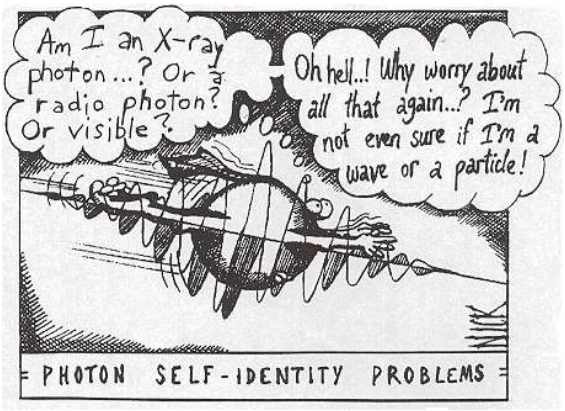

http://commons.wikimedia.org/wiki/Kunstformen_der_Natur

Haeckel (1866) also produced a tree that showed the evolutionary relationships between the various taxa. He coined the terms **phylogeny** and **ontogeny** to differentiate the evolutionary relationships between organisms and the developmental relationships. He noted that **ontogeny recapitulates phylogeny**, something that we saw in the evolution of the eye of hagfish, lamprey and the vertebrates. The original proposal of ontogeny recapitulates phylogeny—that during development, the embryo of higher taxa proceed through embryonic stages that resemble the adult states of the lower taxa that evolved into the higher taxa, has been shown to be of limited value. However, among major taxa, there are similarities between the early stages of embryos which can be used to determine the relatedness of different taxa. In fact, the embryos are so similar that it is difficult to determine if it is an embryo of a pig, cow, rabbit or human. Haeckel popularized evolutionary thinking in *The History of Creation* (1876), *The Riddle of the Universe* (1901), and *The Evolution of Man* (1879-1920).



We have now seen that the **wave-like** and **particle-like** properties of light are useful **models** in describing the absorption, emission, reflection, refraction, diffraction and interference of light in the natural world. In the last lecture I will describe my model of the **photon** and I hope to make the photon, with both particle-like and wave-like properties, completely understandable for you.





Demonstration: In 1929, **Barbara McClintock** (Cornell) visualized and identified the individual **chromosomes** of maize and it is still thrilling to see the **physical basis of heredity** standing out in red against a relatively clear cytoplasm. We will see the colored bodies or **chromo-somes** by putting undehisced anthers dissected from small flower buds in a drop of **acetocarmine** on a slide. We will then tease the anthers apart with **rusty iron** needles; perhaps even ones that belonged to Barbara McClintock, to free the microspores. We will then remove the empty anthers and gently heat the slide for about one second with an alcohol lamp until just before the stain bubbles. We will repeat this step four or five times. Then we will cover the preparation with a cover glass; press on the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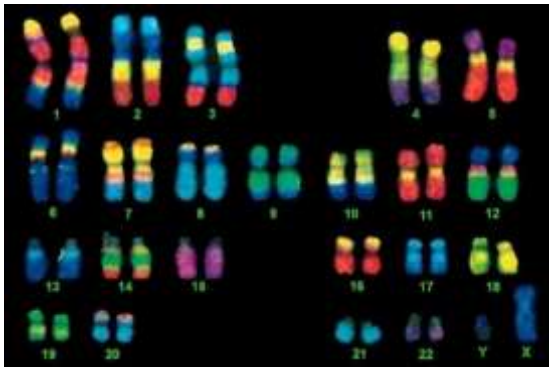
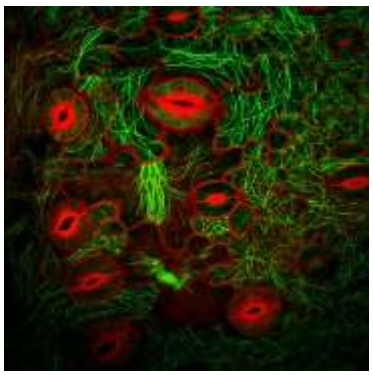
cover glass in order to flatten the cells; and view the preparation with a bright field microscope. *Mirabile dictu*, it never fails, we will literally see the invisible and, at that instant, we will see chromosomes—the physical basis of heredity.



Today, light microscopes can be used to look at chromosomes that have been stained with **fluorescent probes** that identify specific sequences of DNA. This is called **chromosome painting**.



Cells can also be transformed with DNA that encodes any given protein plus a **green fluorescent protein**, a protein naturally involved in **bioluminescence**, to show the spatial distribution of the given protein in a naturally non-luminescent cell. The microtubules that are composed of the tubulin protein are green and, as a consequence of the fluorescence of chlorophyll, the chloroplasts are red.

Microscopes have been inspirational to poets. **Louis Ginsberg**, Allen Ginsberg's father, wrote two poems about the microscope. The second one was discovered in Kroch Library!

Microscope

The more man delves
Into the dark,
The more he enlarges
A question-mark.

Bent like a question
And wonder-eyed,
Man peers at himself,
Magnified.

Microscope

With bated breath and buoyant hope,
Man bends above the microscope;
The question, pulsing deep in dark,
Splinters to many a question mark.

He looks upon a point to check
The tiny, faint and finite speck:
And yet the more he stares and broods,
It swells into infinitudes.

The more he peers into the middle
Of particles that shape the riddle,
The lens, for all that he can see,
But magnifies the mystery . . .

LOUIS GINSBERG.

For as little as $4 to as much as $200, you can turn your smartphone into a light microscope. This is becoming common among health care workers who can use their cell phone and a little dye to diagnose diseases far away from hospitals.

http://www.bhphotovideo.com/bnh/controller/home?O=&sku=970621&gclid=CP6Tz5fc6r0CFUuXOgodqHoA3A&Q=&is=REG&A=details

http://www.newegg.com/Product/Product.aspx?Item=9SIA2C00X84456&nm_mc=KNC-GoogleMKP&cm_mmc=KNC-GoogleMKP-_-pla-_-Camera+Flashes-_-9SIA2C00X84456&ef_id=UmPFEgAAADmFJyib:20140418190402:s

http://the-gadgeteer.com/2014/11/08/attach-this-100x-microscope-to-your-iphone-6-and-become-a-super-hero-scientist/

James Cybulski, James Clements and Manu Prakash (http://www.foldscope.com/#/globalhealth/) developed the **Foldscope**, an origami-based paper microscope that cost's less than a dollar to make and that can be used in the field as "*an integral part of frugal science and engineering*."

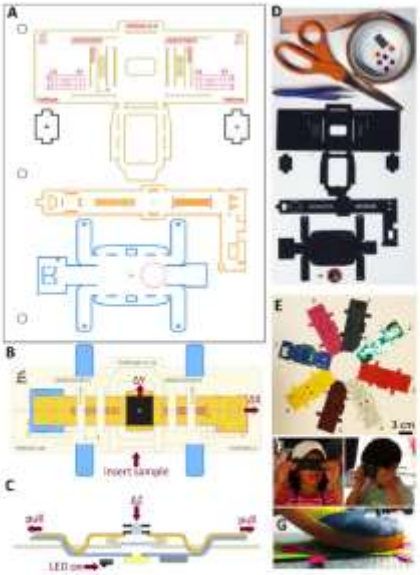


Figure 1. Foldscope design, components and usage. (A) CAD layout of Foldscope paper components on an A4 sheet. (B) Schematic of an assembled Foldscope illustrating panning, and (C) cross-sectional view illustrating flexure-based focusing. (D) Foldscope components and tools used in the assembly, including Foldscope paper components, ball lens, button-cell battery, surface-mounted LED, switch, copper tape and polymeric filters. (E) Different modalities assembled from colored paper stock. (F) Novice users demonstrating the technique for using the Foldscope. (G) Demonstration of the field-rugged design, such as stomping under foot.

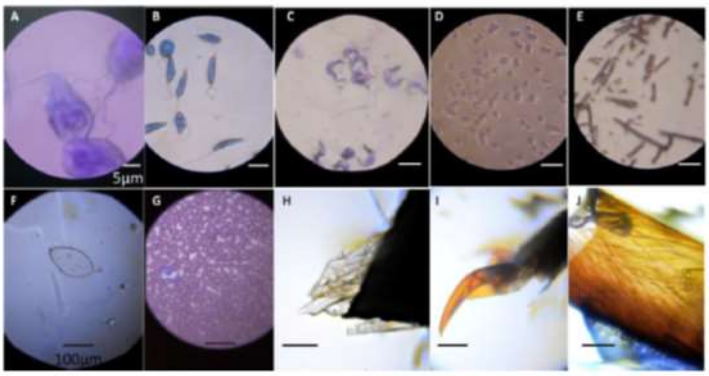
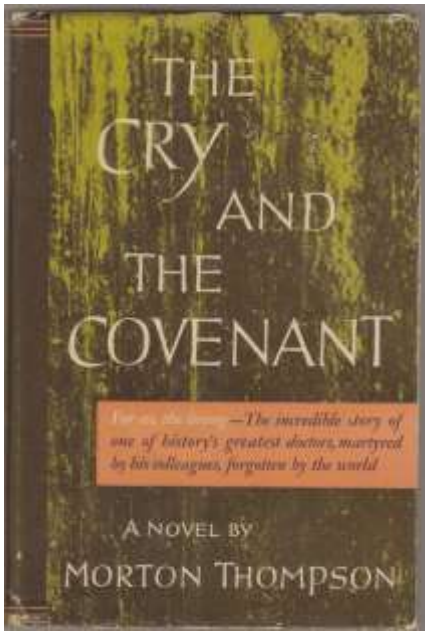


Figure 5. Mosaic of Foldscope Images. Bright field images of (A) *Giardia lamblia* (2,180X), (B) *Leishmania donovani* (1,450X), (C) *Trypanosom Cruzi* (1,450X), (D) gram-negative *Escherichia Coli* (1,450X), (E) gram-positive *Bacillus cereus* (1,450X), (F) *Schistosoma haematobium* (140X), and (G) *Dirofilaria immitis* (140X). Unstained (H) leg muscles and (I) tarsi of an unidentified ladybug (genus *Coccinella*). (J) Unstained leg muscles (fixed in formaldehyde) of an unidentified red ant (genus *Solenopsis*). An LED diffuser (Roscolux #111) was added for (A) and an LED condenser (2.4mm borosilicate ball lens) was used for (C). Images (H-J) were taken by novice user using a self-made Foldscope (140X). See table 2 for ball lenses used for specific magnifications. White scale bar: 5μm; black scale bar: 100μm.

We have come a long way since Ignaz Semmelweis' time in seeing the invisible.



June 7, 1981 New York Times

Graduates Hear Vonnegut On When It's Honorable To Be A 'Wise Guy'

A (Real) Commencement Address

The following remarks are (excerpted) from a speech at the Southampton College commencement last month by the writer Kurt Vonnegut Jr., who has a home on the East End.

"This speech conforms to the methods recommended by the United States Army Manual on how to teach. You tell people what you're going to tell them. Then you tell them, then you tell them what you told them.

Now we'll first discuss honorable behavior, especially in peacetime, and we'll then comment on the information revolution - the astonishing fact that human beings can actually know what they're talking about in case they want to try it. From there, I will go on to recommend to those graduating from colleges everywhere in the world this spring that their hero be **Ignaz Semmelweis**.

You may laugh at such a name for a hero, but you will become most respectful, I promise you, when I tell you how and why he died.

After I describe Ignaz Semmelweis a little, I will ask if he might not represent the next stage of human evolution. I will conclude that he had better be. If he doesn't represent what we're going to become next, then life is all over for us and for the cockroaches and the dandelions too.

I will give you a hint about him. He saved the lives of many women and children. If we continue on our present course there will be less and less of that going on. O.K…..

The thing I give you to cling to is a poor thing, actually. Not much better than nothing, and maybe it's a little worse than nothing. I've already given it to you. It is the idea of a truly modern hero. It is the bare bones of the life of Ignaz Semmelweis. My hero is Ignaz Semmelweis. You may be wondering if I'm going to make you say that out loud again. No, I'm not, you've heard it for the last time.

He was born in Budapest in 1818. His life overlapped with that of my grandfather and with that of your great-grandfathers and it may seem a long time ago to you, but actually he lived only yesterday.

He became an obstetrician, which should make him modern hero enough. He devoted his life to the health of babies and mothers. We could use more heroes like that. There's damn little caring for mothers or babies or old people or anybody physically or economically weak these days as we become ever more industrialized and militarized with the guessers in charge.

I have said to you how new all this information is. It is so new that the idea that many diseases are caused by germs is only about l20 years old.

The house I own out here in Sagaponack is twice that old. I don't know how they lived long enough to finish it. I mean the germ theory is really recent. When my father was a little boy, Louis Pasteur was still alive and still plenty controversial. There were still plenty of high-powered guessers who were furious at people that would listen to him instead of to them. Yes, and Ignaz Semmelweis also believed that germs could cause diseases. He was horrified when he went to work for a maternity hospital in Vienna, Austria, to find out that one mother in 10 was dying of childbed fever there.

These were poor people - rich people still had their babies at home. Semmelweis observed hospital routines, and began to suspect that doctors were bringing the infection to the patients. He noticed that the doctors often went directly from dissecting corpses in the morgue to examining mothers in the maternity ward. He suggested as an experiment that the doctors wash their hands before touching the mothers.

What could be more insulting. How dare he make such a suggestion to his social superiors. He was a nobody, he realized. He was from out of town with no friends and protectors among the Austrian nobility. But all that dying went on and on and Semmelweis, having far less sense about how to get along with others in this world than you and I would have, kept on asking his colleagues to wash their hands.

They at last agreed to do this in a spirit of lampoonery, of satire, of scorn. How they must have lathered and lathered and scrubbed and scrubbed and cleaned under their fingernails. The dying stopped - imagine that! The dying stopped. He saved all those lives.

Subsequently, it might be said that he has saved millions of lives - including quite possibly yours and mine. What thanks did Semmelweis get from the leaders of his profession in Viennese society, guessers all? He was forced out of the hospital and out of Austria itself, whose people he had served so well. He finished his career in a provincial hospital in Hungary. There he gave up on humanity, which is us, and our knowledge, which is now yours, and on himself.

One day in the dissecting room, he took the blade of a scalpel with which he had been cutting up a corpse, and he stuck it on purpose into the palm of his hand. He died, as he knew he would, of blood poisoning soon afterward.

The guessers had had all the power. They had won again. Germs indeed. The guessers revealed something else about themselves too, which we should duly note today. They aren't really interested in saving lives. What matters to them is being listened to -as however ignorantly their guessing goes on and on and on. If there's anything they hate, it's a wise guy or a wise girl.

Be one anyway. Save our lives and your lives too. Be honorable. I thank you for your attention."