Fundamentals of Imaging
Image acquisition: analog

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This slide pack

- All about capturing
  - Film
  - Sensors

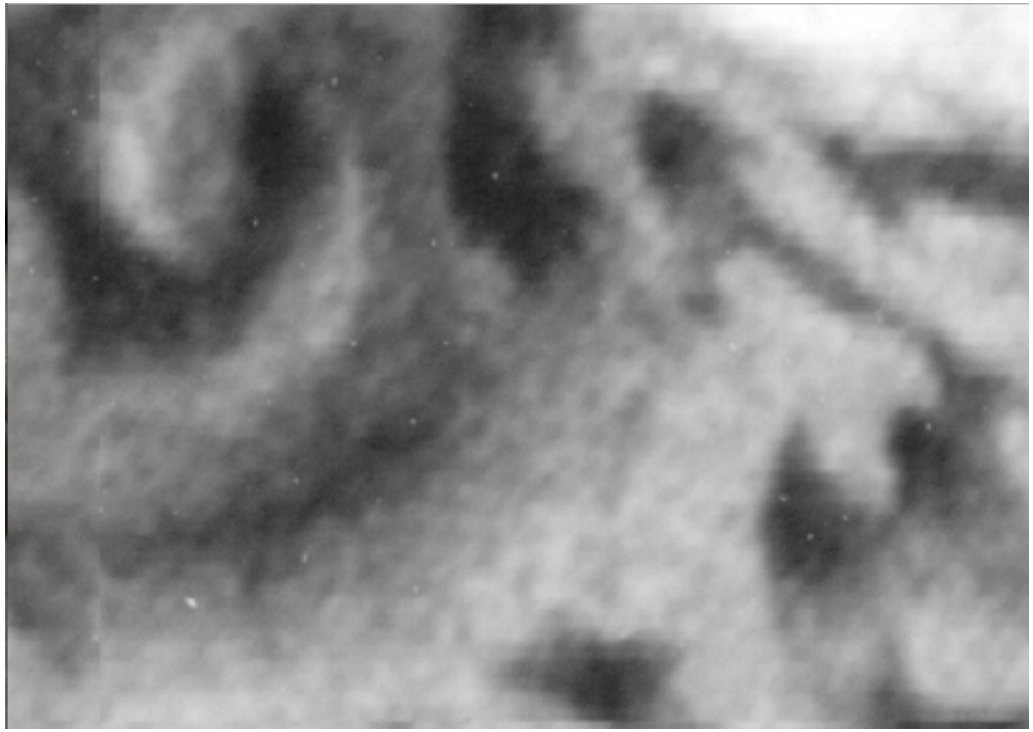
Image capture

- Image capturing is done through
  - photosensitive material (analogue film) or
  - photosensitive electronics (which uses photoelectric phenomenon)
- Analog film is still used for artistic purposes or by professionals due to quality factors
- Electronic cameras have a very wide diffusion, due to simplicity of use and to ease of use in postprocessing
  - Moreover, their images can be stored directly on computers, eliminating the need for storing space

Black and white film

- Made by silver halide crystals dispersed in gelatin
- Process invented in 1834 (daguerreotype)
  - First: single emulsion layer coated on glas
- Now coated on support material
  - cellulose triacetate
  - sometimes on PETP
- Coating <10μm

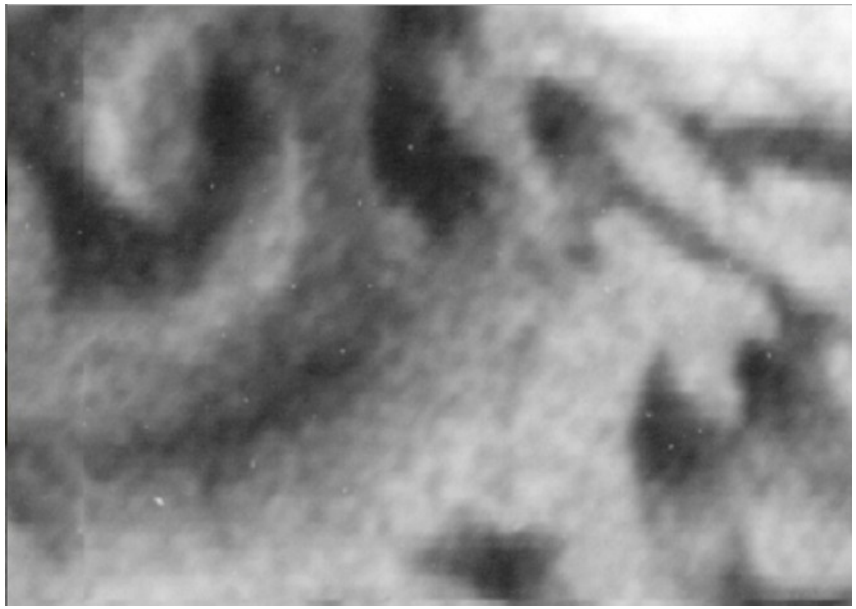
- Silver halide crystal (grains) are sensitive material
- Shape of grains: mostly triangular, but also circular, square, hexagonal, irregular.



Black and white film

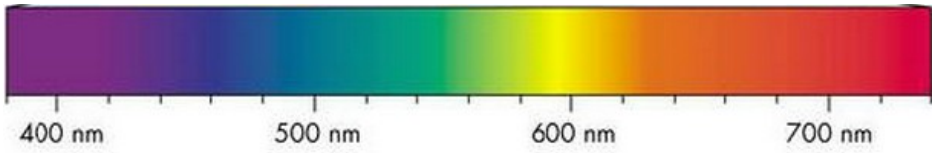
- In most consumer films, grain size distribution can be described as
  $f(a)=A_0 exp[-K(ln\ a/a_0)^2] + A_1 exp[-K(ln\ 1/a_1)^2]$
  where
  - a grain size,
  - a_0 and a_1 peak grain sizes,
  - A_0 and A_1 constants,
  - K measure of distribution spread.
- Film contrast reduces with spread of grain distribution
- Speed of film increases with bigger grain sizes
- Typical grain sizes: 0.2-0.7μm^2 thus ca. 0.45μm = ca.5.6 million dots per inch

- For comparison, a 24Mpixel APS-C camera sensor has a pixel area of 13.68μm^2
- Other sources quote a 100 ASA film in 24x36 size as equivalent to 2000x3000 pixels (?)
- Gelatin prevents grains from aggregating, allowing the developer to act on individual grains



Black and white film: latent image

- The structure of silver halide crystals has various defects:
  - Kinks
  - Lattice dislocations
- These serve as photon traps or holes
- When photon absorbed by crystal it can create a photon-hole pair
  - The electron can be trapped by silver ion, creating an image latent center
  - Or wander around and recombine a hole, which means loss of detection efficiency
- It then makes silver aggregates in the crystal
- When silver atoms are in a number of 3-6 they can be developed by the developer
- Image latent centres are stable and can survive, undeveloped, years
- However, it takes 3-10 times as much photon absorptions to form an image latent center, because most photon-generated electrons are lost in photon-hole recombinations
- Photon absorption occurs at wavelengths below 500nm:
  - higher wavelengths are captured with organic dies absorbing photons in remaining regions
  - The die liberates electrons, which contribute to the silver aggregates in the grain (sensitizing dies)

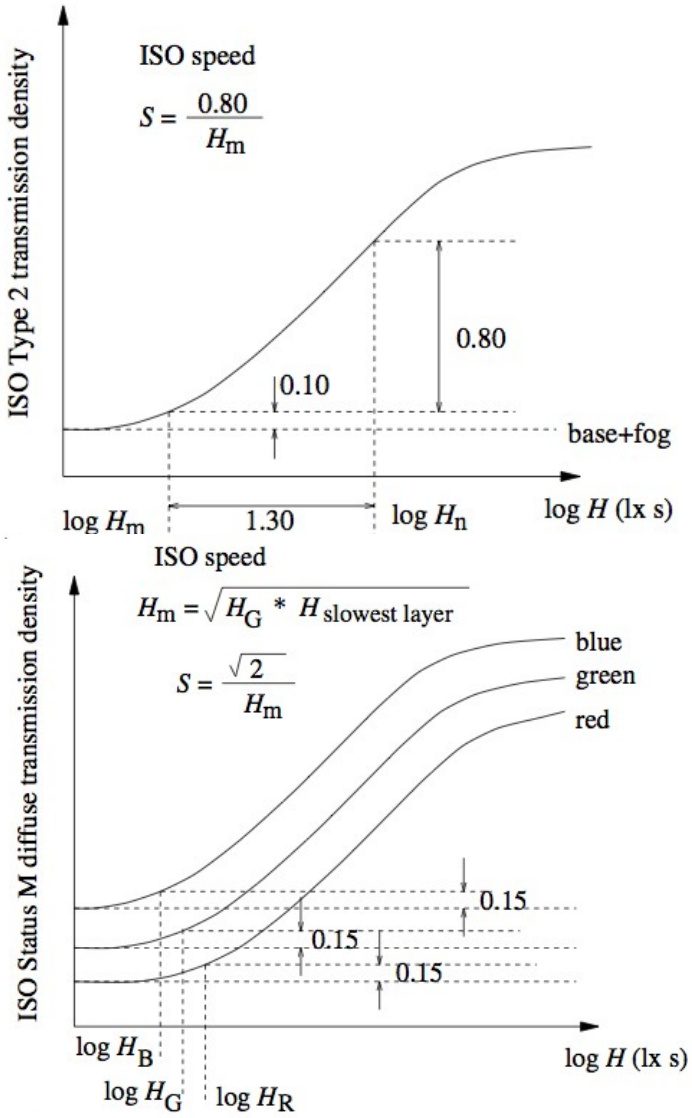


Black and white film: developing

- A developer is a reduction agent: it donates electrons
  - Thus it transforms silver ions into silver atoms
  - Photo reduction agents act on exposed grains several degrees of magnitude faster than on unexposed grains
  - Once silver image is created, the rest of the undeveloped grains are washed away (*Fixing*)
- After fixing, one has a negative image:
  places with high exposure have lots of silver
- Where lots of silver is present, light does not get transmitted or reflected, forming the negative image
- To form a positive image instead, other chemicals are used which wash away developed silver.
- Remaining grains are developed in silver grains, forming a positive image (reverse processing) (like Dias)
- Some grains might be developed even if not exposed ⇒ fog
- Other components might contribute to fog, like emulsion or printing paper, creating additional fog density (=basic noise)

Film: sensitometry and densitometry

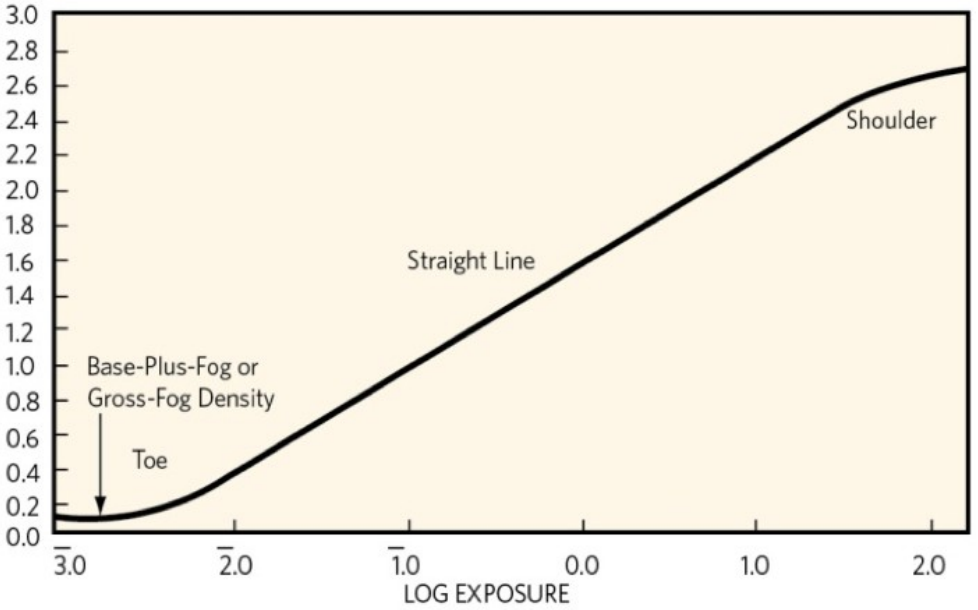
- Film response to light: density due to exposure on film before development
- Plot of density as function of log exposure is called *characteristic curve of film*
- For color, the 3 RGB curves are plotted
- BW: speed S := $0.80/H_m$, where H_m = exposure (in lux seconds) at which film has been developed to a density of 0.10 above base plus fog density
- Color: $\sqrt{2}/H_m$, with H_m geometric mean of H_G and the maximum of H_G, H_R, H_B (this time 0.15 above base plus fog density



Black and white film: pushing

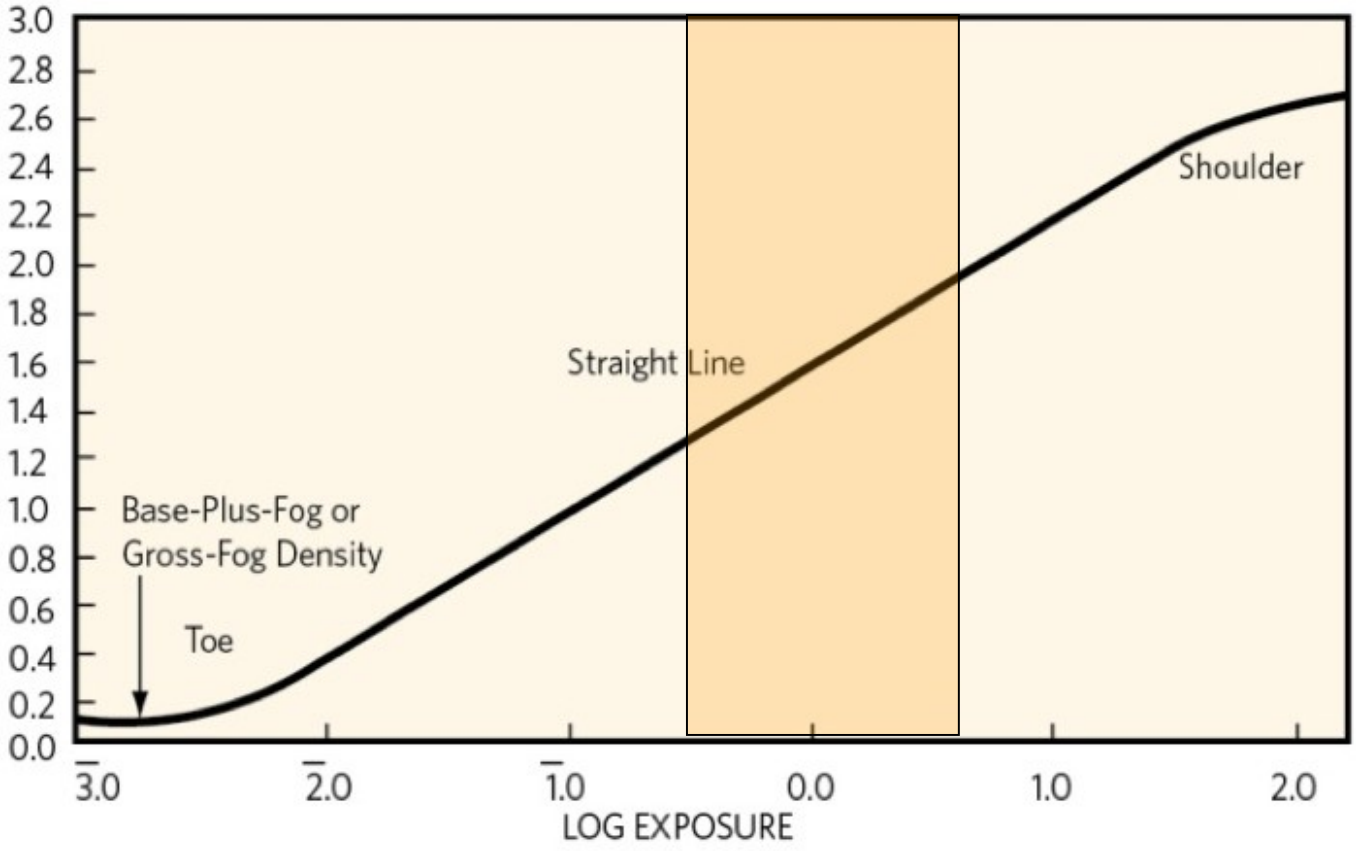
- Developing times (how long developer exposes the film) are determined through experiment
- One can “increase” light sensitivity of film by underexposing it and develop longer
- This compensates higher graininess for higher sensitivity
- This process is called “pushing” film
- “pulling” is the reverse, but rarely used

- Problem here is film light sensitivity curve:



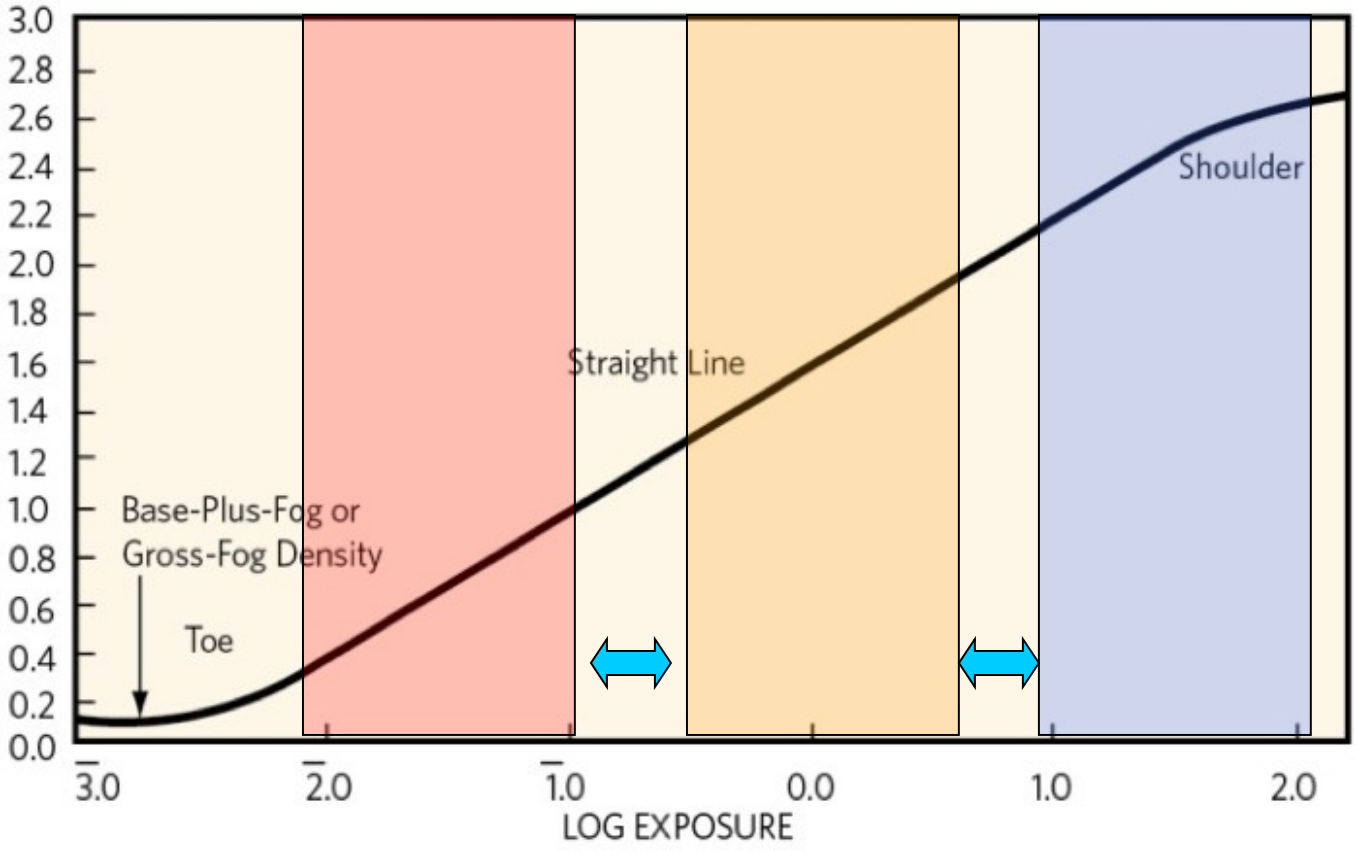
Black and white film: pushing

- Producers would set ISO rate on a window of the curve optimal for film characteristics



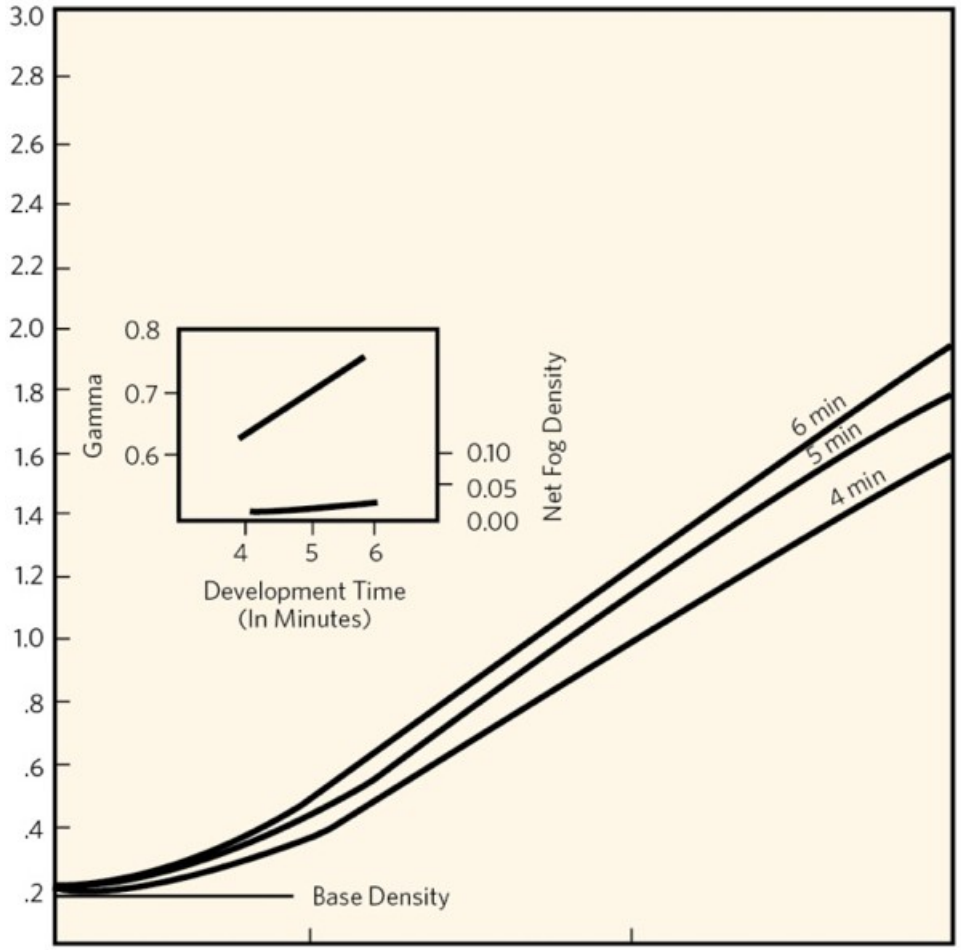
Black and white film: pushing

- One can move such window



Black and white film: pushing

- How? By increasing/decreasing development time



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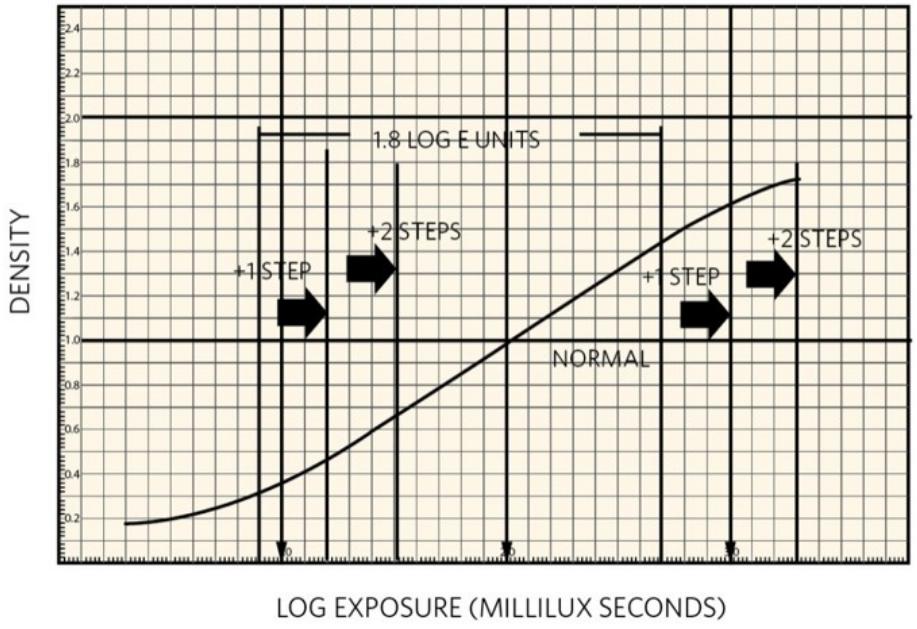

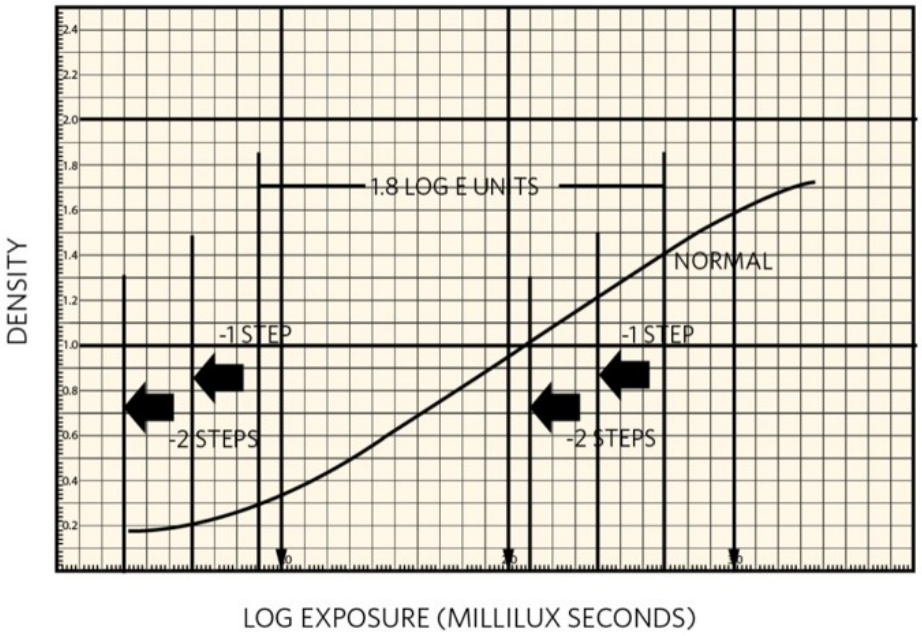

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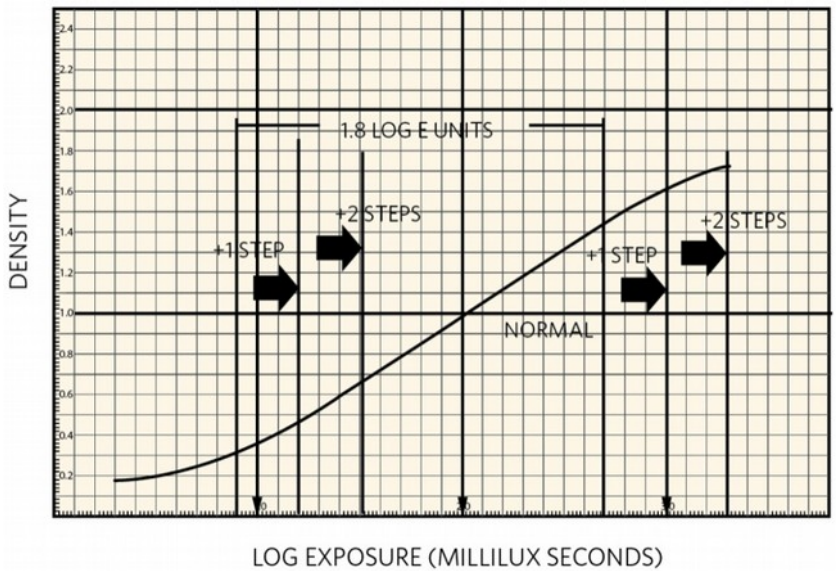
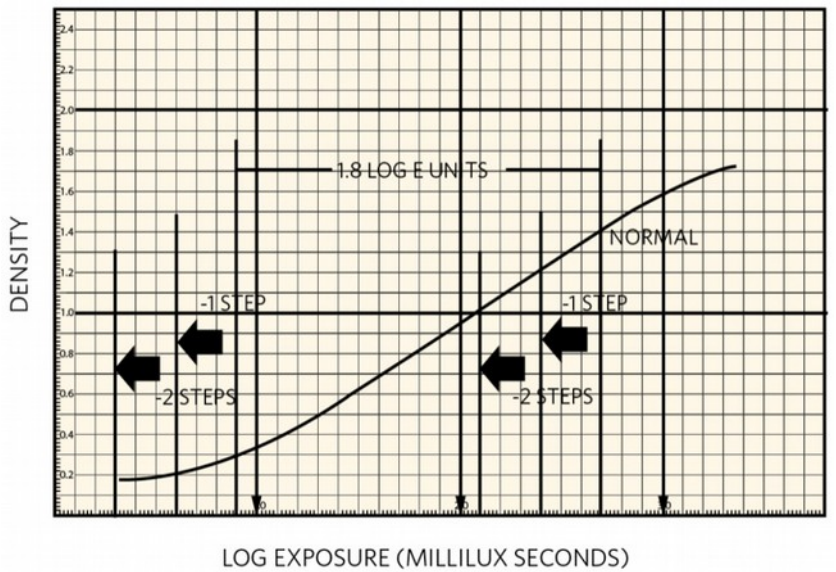


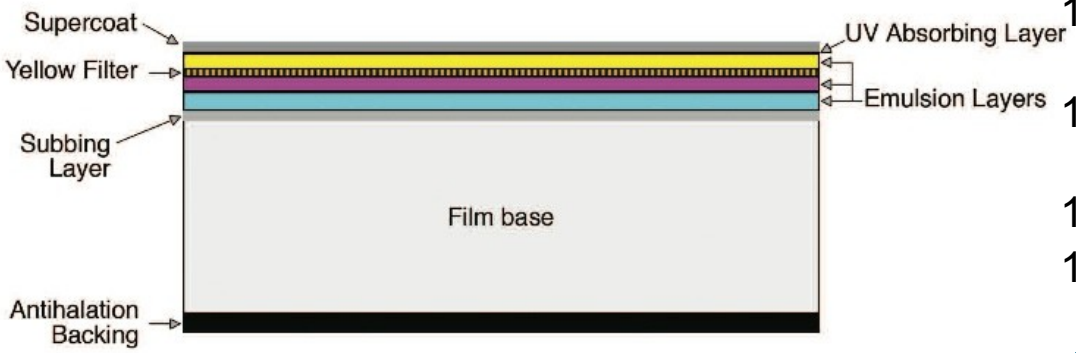


Black and white film: pushing

- This results in crude shades, especially when pusing is done on the shoulder, since less grayscale resolution is available
- Like night photography in the 50s-70s: very black darks

Colour photography

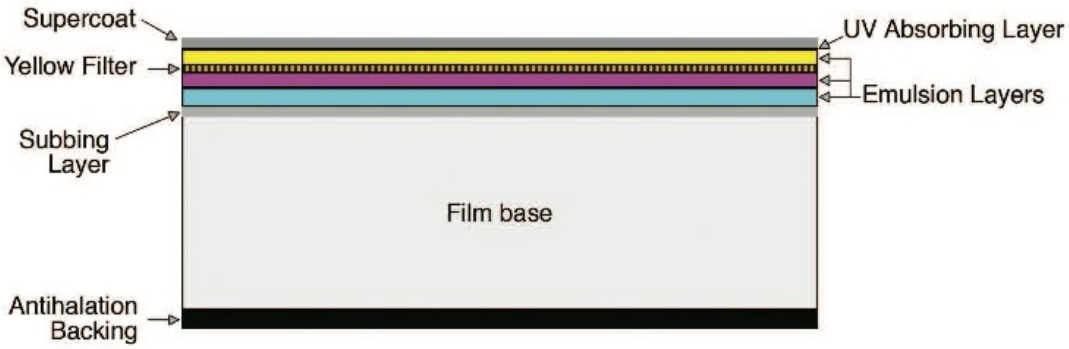
- Our visual system works tri-chromatically:
  - Color films use this:
    - Low wavelength (red)
    - Middle wavelength (green)
    - High wavelength (blue)
  - Red-green also sensitive to blue
  - Sensitivity is enhanced through sensitizing dyes
- The three coatings are layered one on top of each other
  - Red coating at back
  - Green coating next
  - A yellow filter
  - Blue on top
- Yellow filter absorbs the blue, leaving the lower layers exposed to right light (R-G)
- Modern films may contain up to 15 layers, each of which 0.1μm thick:



1. overcoat
2. absorber,
3. ultraviolet filter,
4. high-speed (coarse-grain) blue-sensitive emulsion,
5. low-speed (fine grain) blue-sensitive emulsion,
6. yellow filter,
7. active separating layer,
8. high-speed green-sensitive emulsion layer,
9. low-speed green-sensitive emulsion layer,
10. red filter layer,
11. high-speed red-sensitive emulsion layer,
12. low- speed red-sensitive emulsion layer,
13. antihalation coating, and
14. film base (cellulose acetate)

Colour photography

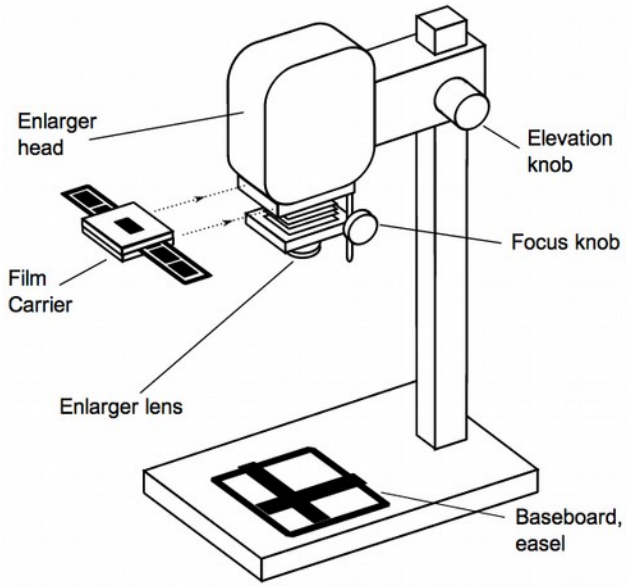
- Question is: how do I develop the layers?
- There are two ways of doing this:
  - put image dyes in the developers:
    image dye is formed when latent image centers are developed (Kodachrome)
  - put image dye precursors into the emulsion layers: image dyes are formed when latent silver image is developed (all others)
- Reducing agent gets oxidized when it reduces silver ions.
- Chemicals (*couplers*) are put in emulsion that react with oxidized developer
- This makes an image proportional to silver image
  - Cyan coupler
  - Magenta coupler
  - Yellow coupler



Analogue colour printing

- Once a negative is produced, it can be printed to photographic paper
- Photo paper has the same light sensitive materials:
  - 2x negative=positive
- Reproduction is done by testing exposures to get best possible light exposure (by hand) for the enlarger
- An enlarger is an optical projector (film beamer)
- Paper is exposed correct time and develops properly with similar chemical process to film
  - Thus the 3 baths

- For colour, enlargers are used having 3 colour components exposing paper to Y,C,M light.
- Paper is sensitive to the 3 different light frequencies, and develops accordingly



Analogue link

- Check this excellent explaination of the chemical process:

  http://www.film-photography-blog.com/film-processing-chemistry-how-does-it-work/

A little magic…

Darkroom in Use: https://www.youtube.com/watch?v=nue495wxlXo