

Acquisition et Formation d'Image - Lumière, caméra, optique et couleur

Sommaire

- Introduction
- Caméras à lentilles
 - Profondeur de mise au point
 - Champ de vision
- Vision humaine
- Caméras Numériques
 - Types de détecteurs

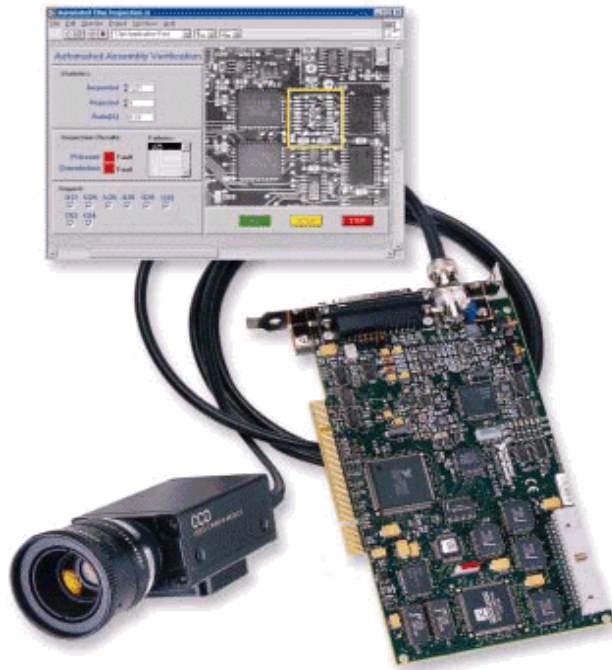
A Fun!



A Fun! **Illusion de lavabo**



Formation des images : Introduction



	0	1	2		c										$n-1$
0	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i
1	i	i	i	i	i	i	i	5	i	i	i	i	i	i	i
2	i	i	i	i	i	5	5	5	3	5	i	i	i	i	i
	i	i	i	i	i	5	5	3	5	i	i	i	i	i	i
	i	i	i	i	i	5	3	3	5	i	i	i	i	i	i
j	i	i	i	i	i	i	i	5	3	5	i	i	i	i	i
	i	i	i	i	i	i	i	i	5	i	i	i	i	i	i
	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i
$m-1$	i	i	i	i	i	i	i	i	i	i	i	i	i	i	i



Une image est un tableau de m lignes et n colonnes
Chaque case contient un nombre auquel est associé une 'couleur' de pixel.

	0	1	2		c										$n-1$
0															
1															
2															
j															
$m-1$															

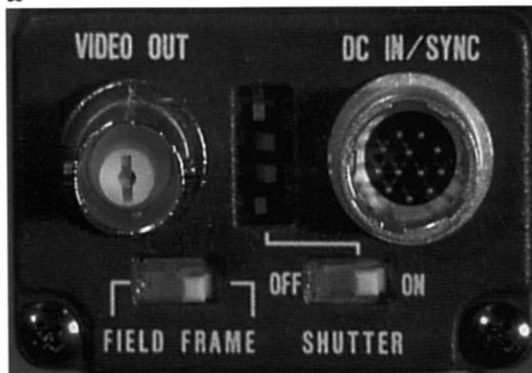
On appelle Traitement d'Images Numériques (Digital Image Processing) le traitement d'une image bidimensionnelle (2D) par un ordinateur.

Dans le traitement digital de l'image, le système d'acquisition convertit l'image en une matrice de points appelés pixels (contraction de picture element)

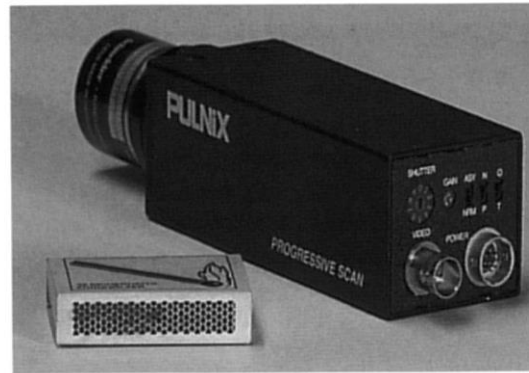
Une Image numérique est donc un tableau de nombres de taille $n*m$.

Dispositifs d'acquisition

a



b

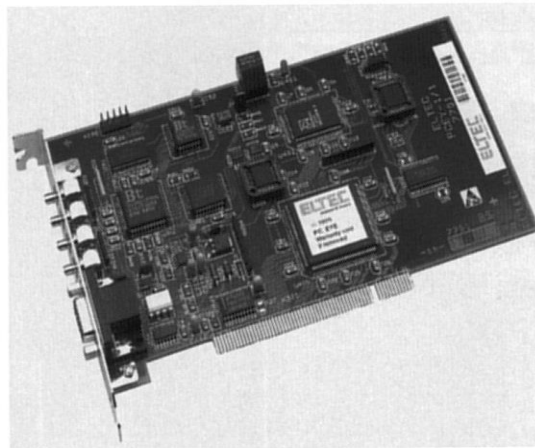


- Caméra
- Objectifs

a

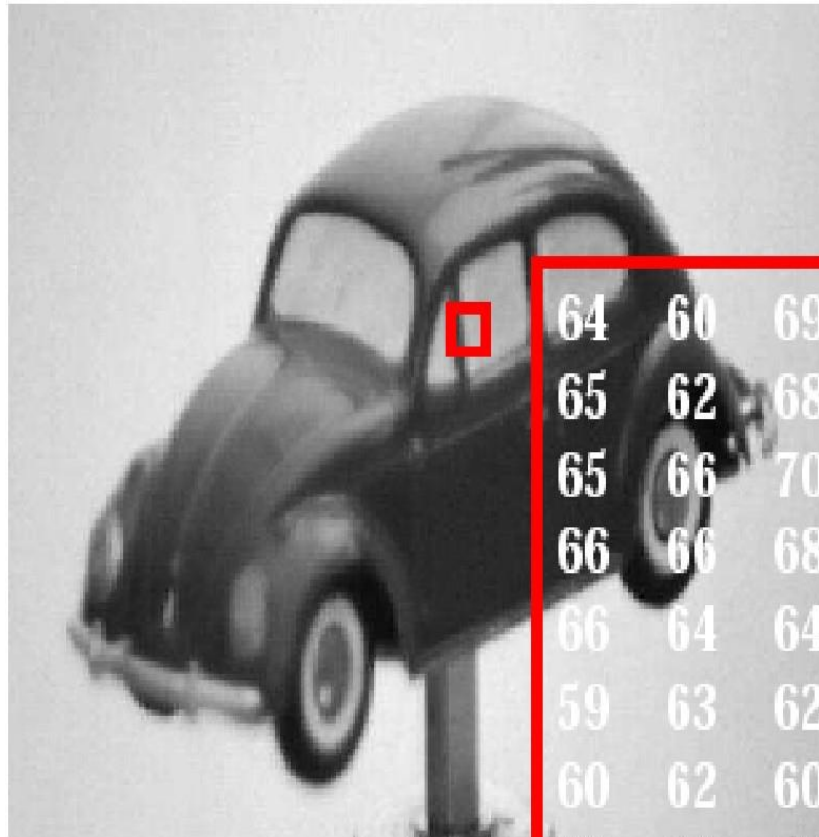


b



- Carte électronique d'acquisition

Qu'est ce qu'une image ?



Niveaux de gris - 8 bits:

0 - noir

255 - blanc

64	60	69	100	149	151	176	182	179
65	62	68	97	145	148	175	183	181
65	66	70	95	142	146	176	185	184
66	66	68	90	135	140	172	184	184
66	64	64	84	129	134	168	181	182
59	63	62	88	130	128	166	185	180
60	62	60	85	127	125	163	183	178
62	62	58	81	122	120	160	181	176
63	64	58	78	118	117	159	180	176

Qu'est ce qu'une image ?

Quelques éléments simples d'une image



Une zone homogène



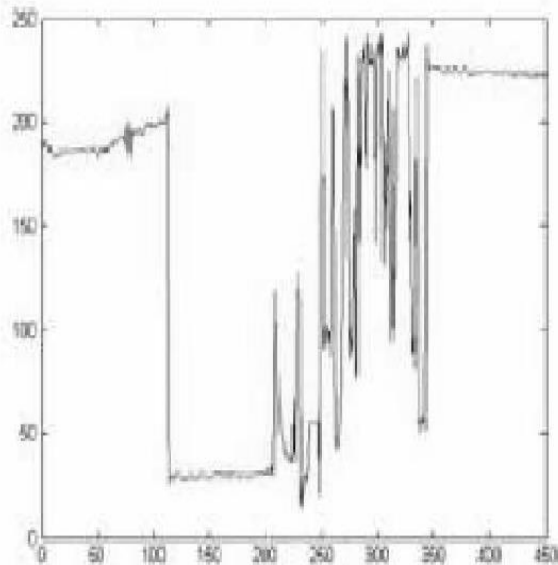
Une texture



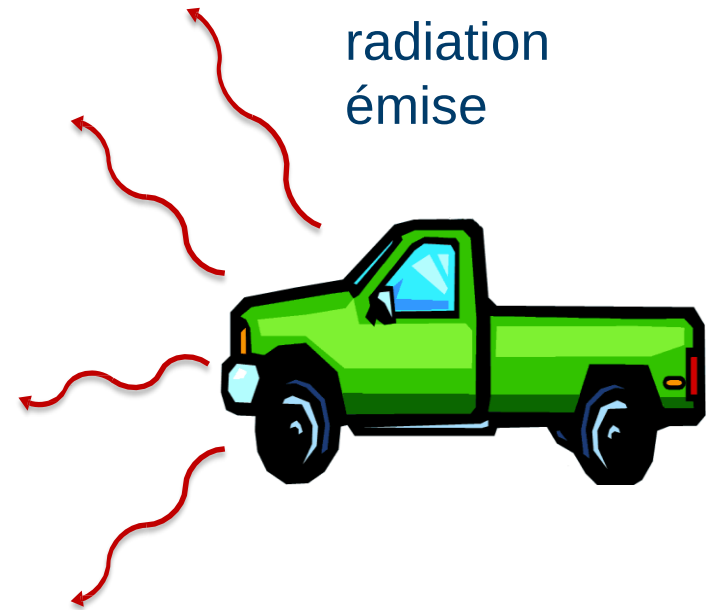
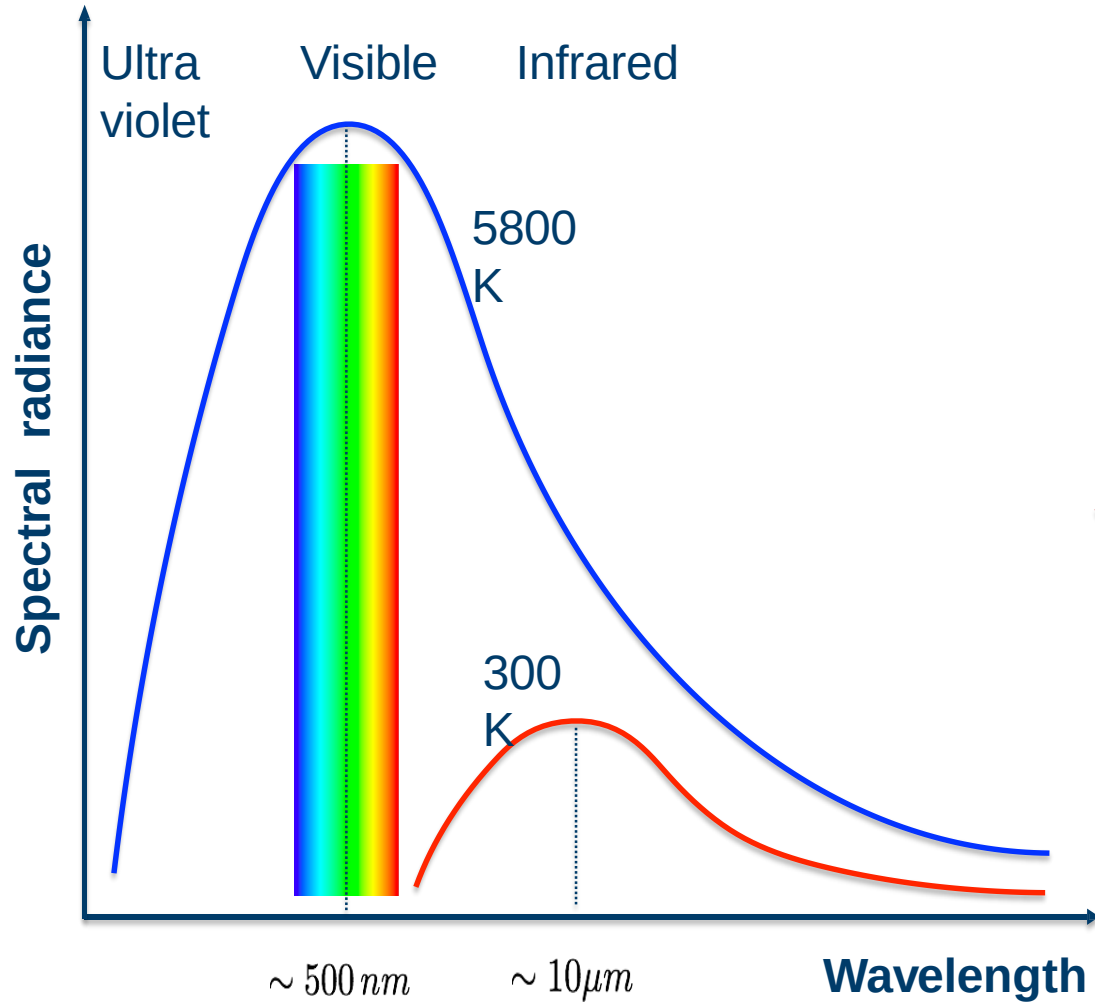
Un contour

Qu'est ce qu'une image ?

Un profil d'intensité d'une ligne dans une image est un signal 1D



Thermal radiation - Planck distribution



Types d'Images par réflexion et émission de radiation lumineuse



Image en lumière visible



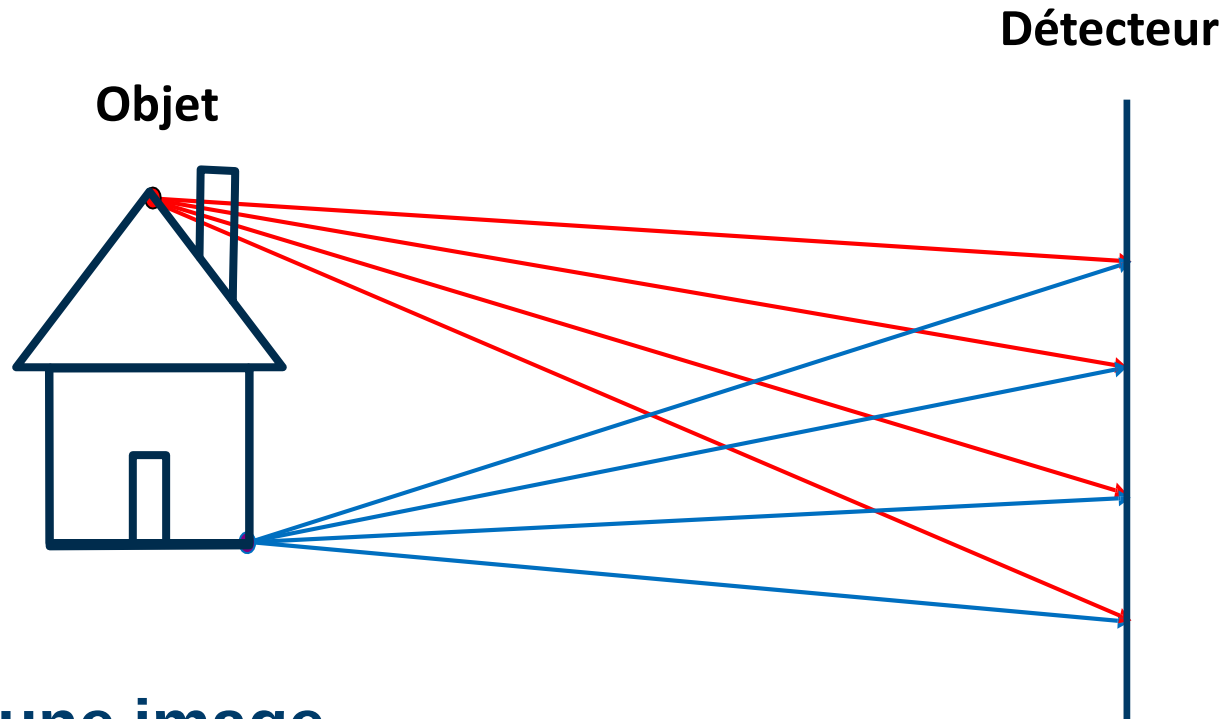
Image infrarouge (thermique)

Autres domaines de fréquences et types d'ondes utilisés en imagerie:

- Millimeter waves, x-rays, ... (electromagnetic waves)
- Acoustic (sonar), seismic, ... (mechanical waves)



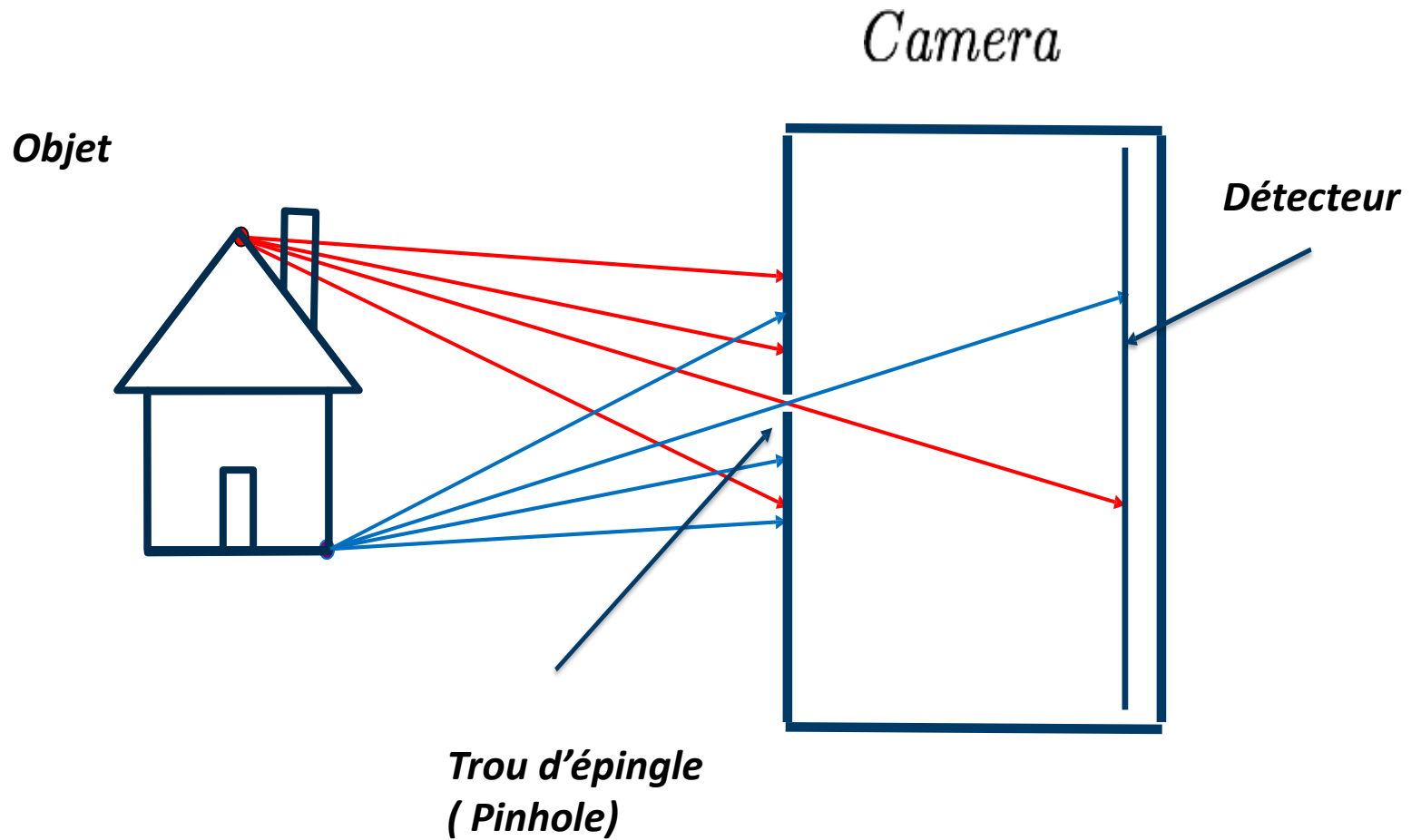
Comment se forme une image?



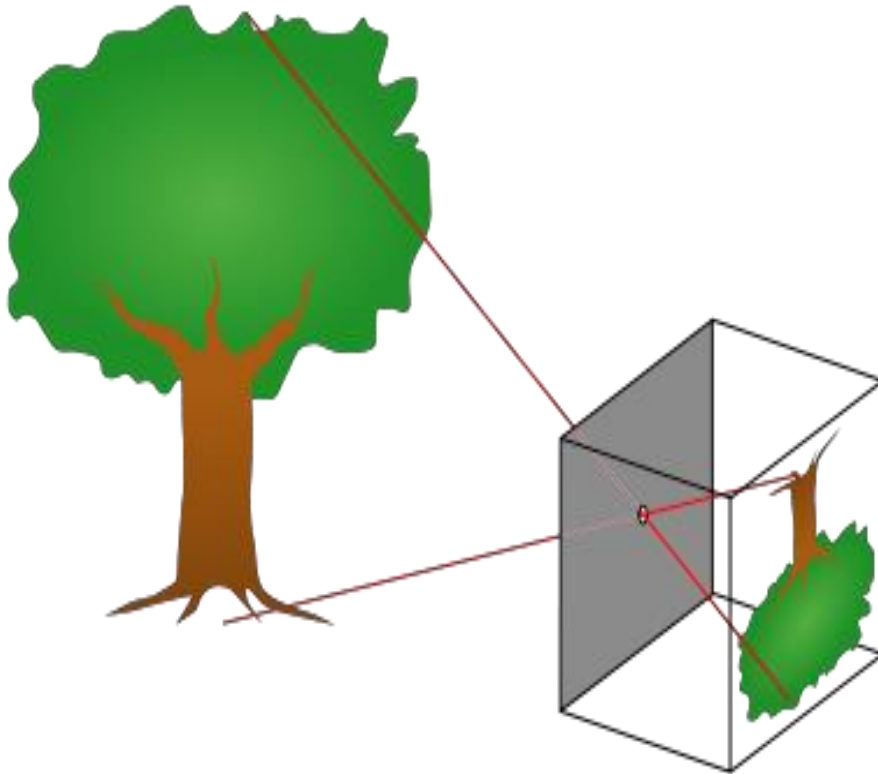
**Aucune image
n'est formée!**

Simple caméra -

Pinhole camera



Pinhole camera



Petite
ouverture



Image noire

Large
ouverture

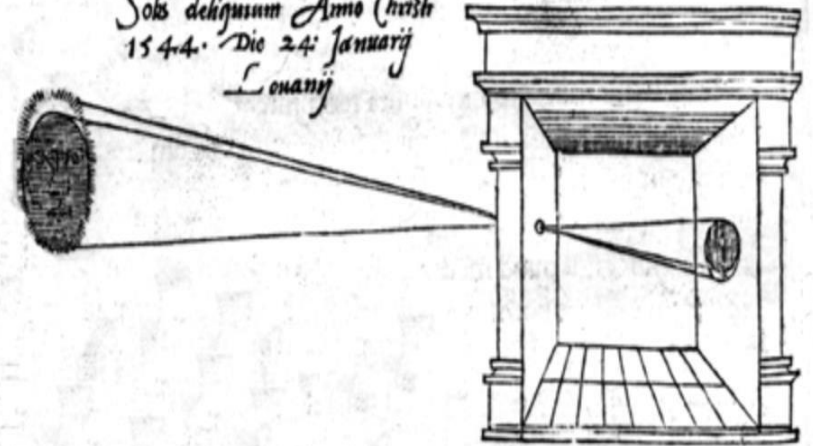


Image floue

Camera obscura

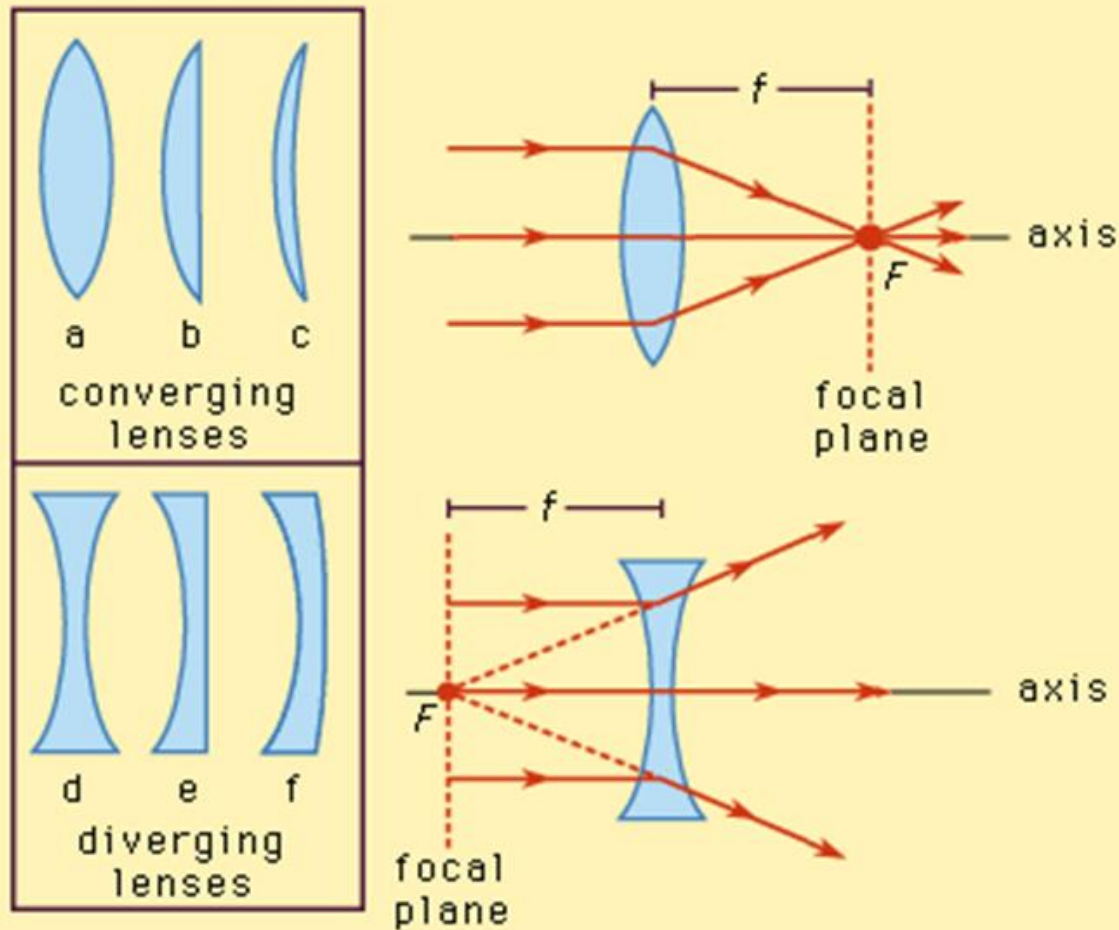
illum in tabula per radios Solis, quàm in cælo contin-
git: hoc est, si in cælo superior pars deliquiū patiatur, in
radiis apparebit inferior deficere, vt ratio exigit optica.

*Solis deliquium Anno Christi
1544. Die 24. Januarij
Louanij*

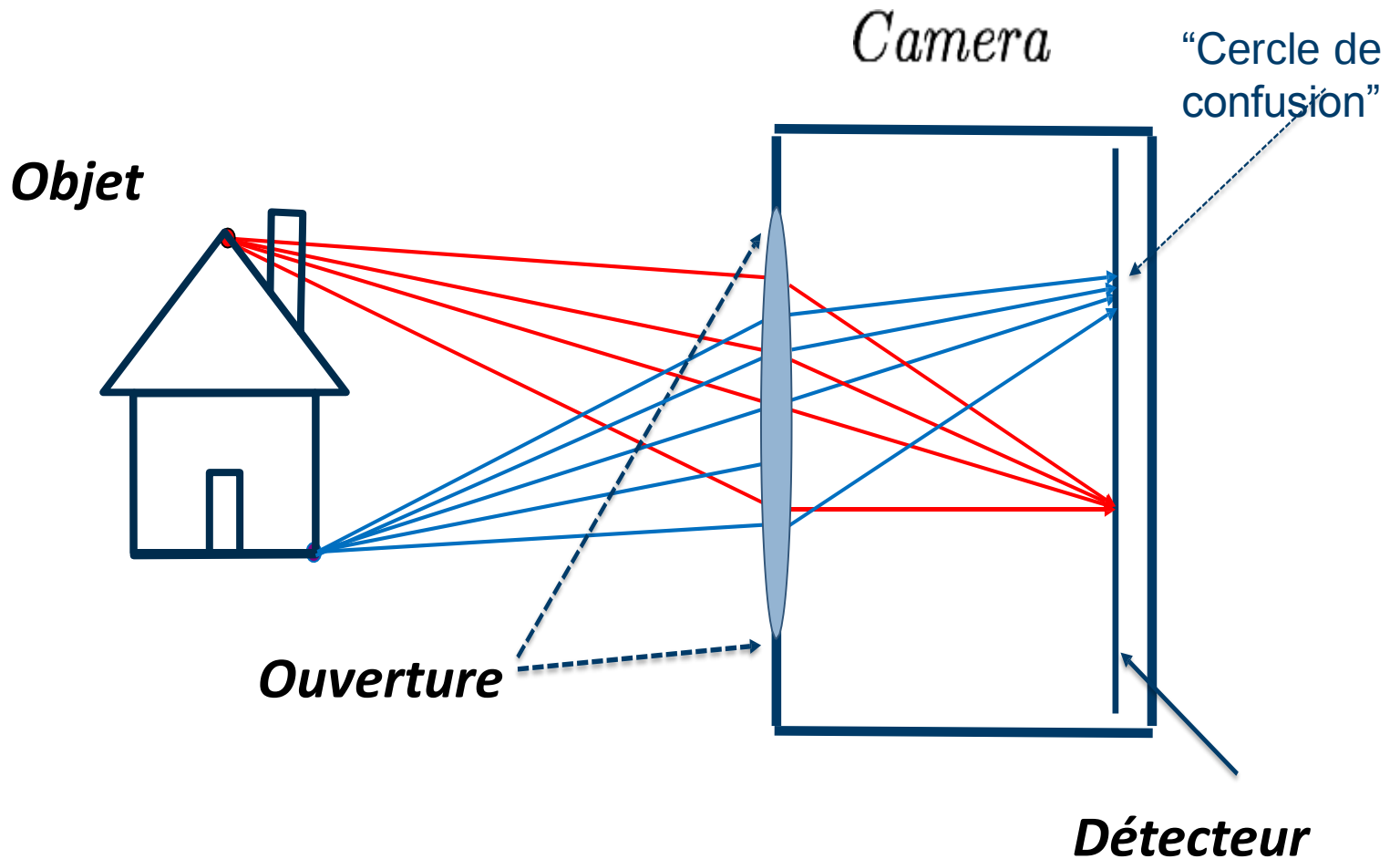


Sic nos exactè Anno .1544. Louanii eclipsim Solis
obseruauimus, inuenimusq; deficere paulò plus q̃ dex-

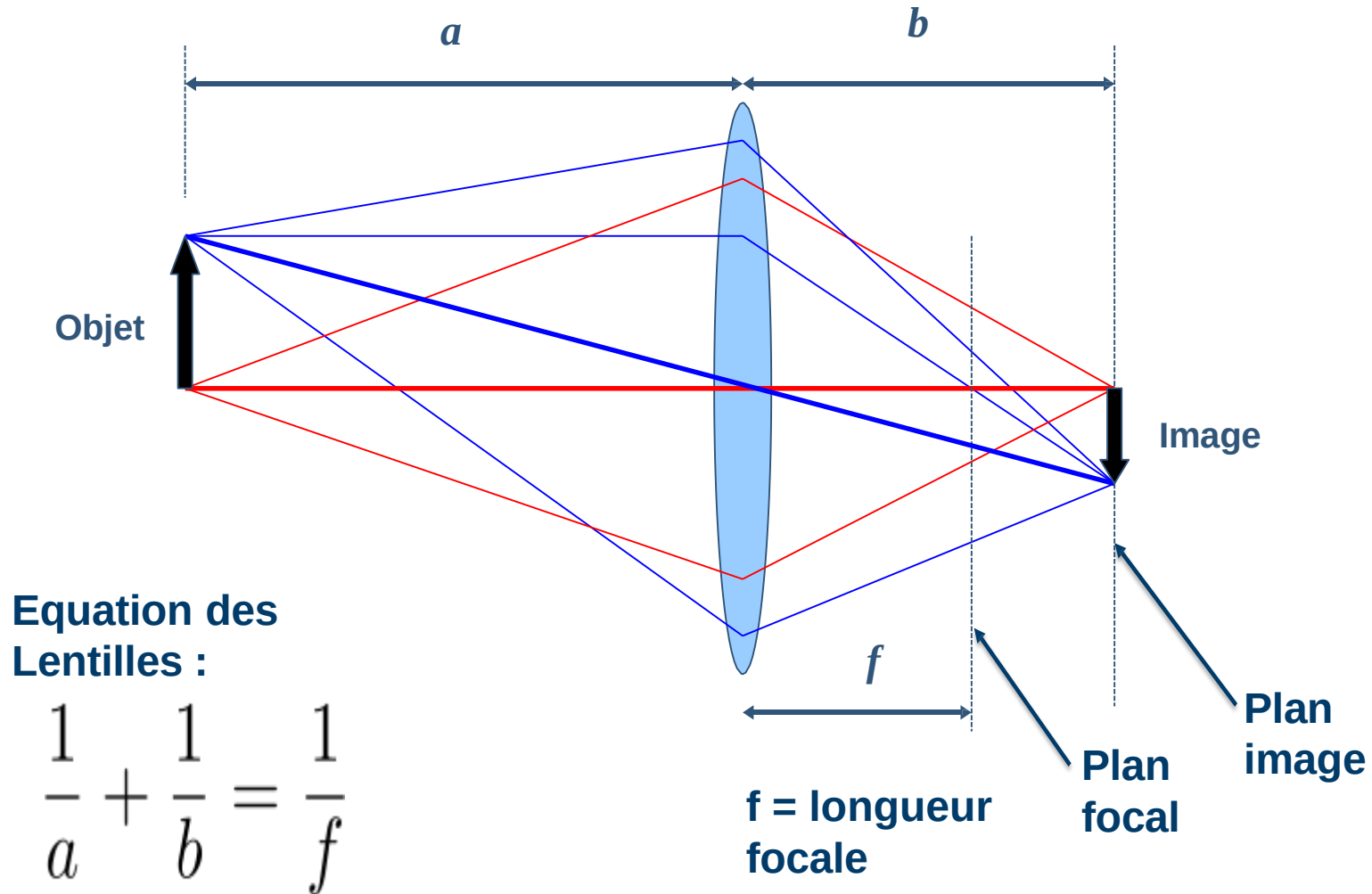
Caméras à lentilles



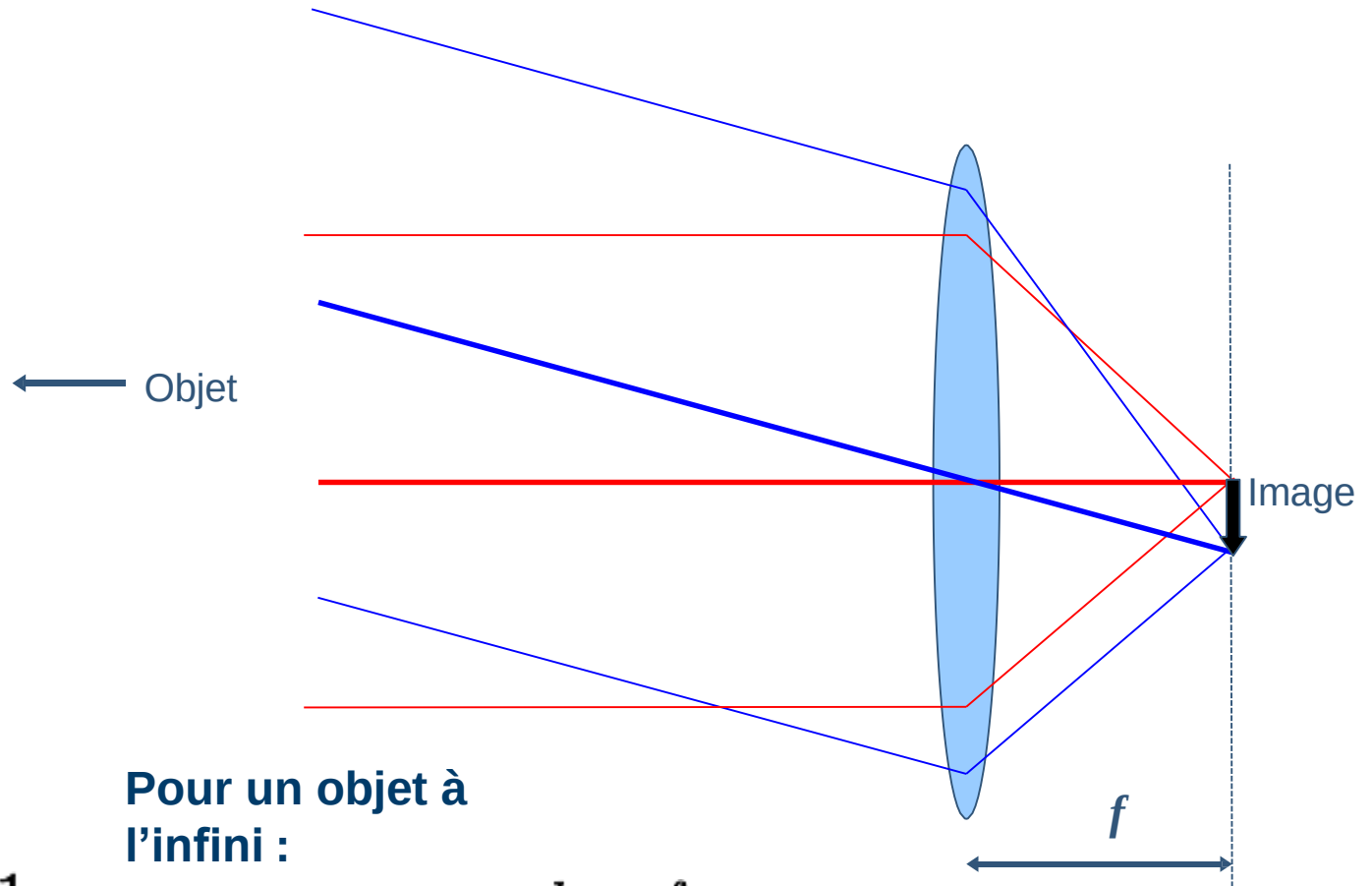
Caméra à lentilles



Imagerie à lentilles



Objet à l'infini



Equation des
Lentilles :

$$\frac{1}{a} + \frac{1}{b} = \frac{1}{f}$$

Pour un objet à
l'infini :

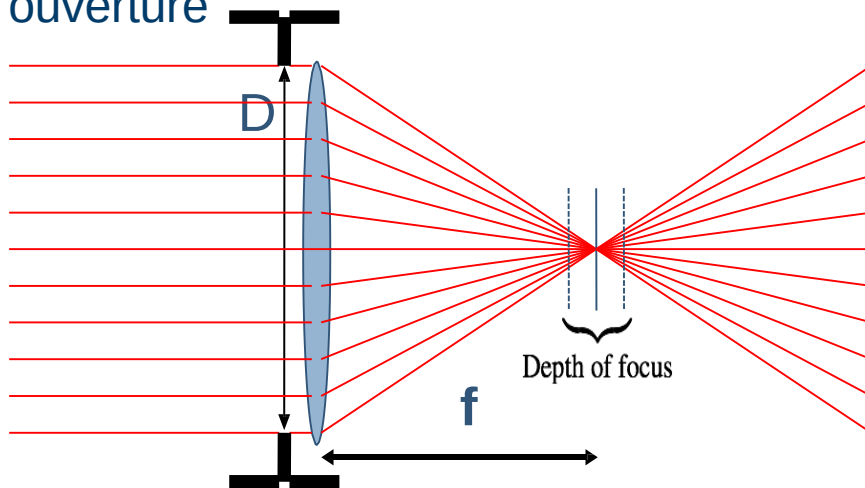
$$a = \infty \Rightarrow b = f$$

i.e. image est formée
dans le plan focal .

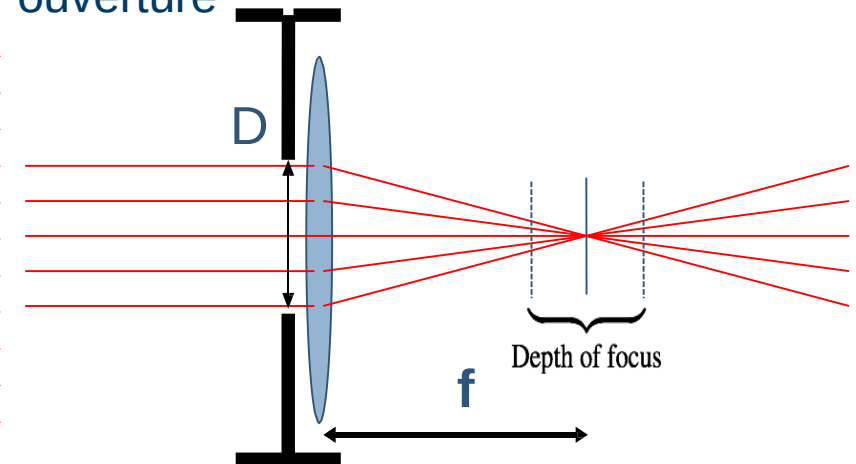
Profondeur de mise au point

Depth of focus

Grande
ouverture



Faible
ouverture

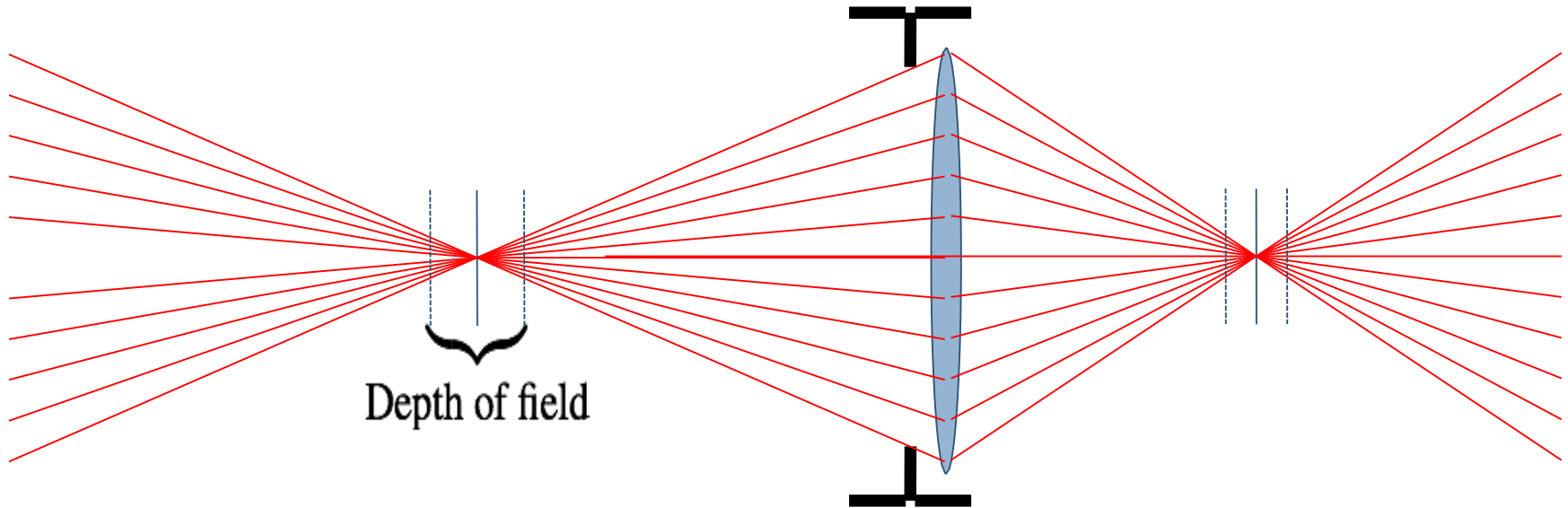


F-number: f/D (examples: $f/2.8$, $f/4$, $f/5.6$, $f/8$, $f/11$, $f/22$)

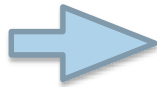
Petit f-nombre ➡ Profondeur de mise au point étroite ➡ Large f-nombre ➡ Large profondeur de prise de vue

Profondeur de champ – grande ouverture

Depth of field – large aperture



Large
ouverture

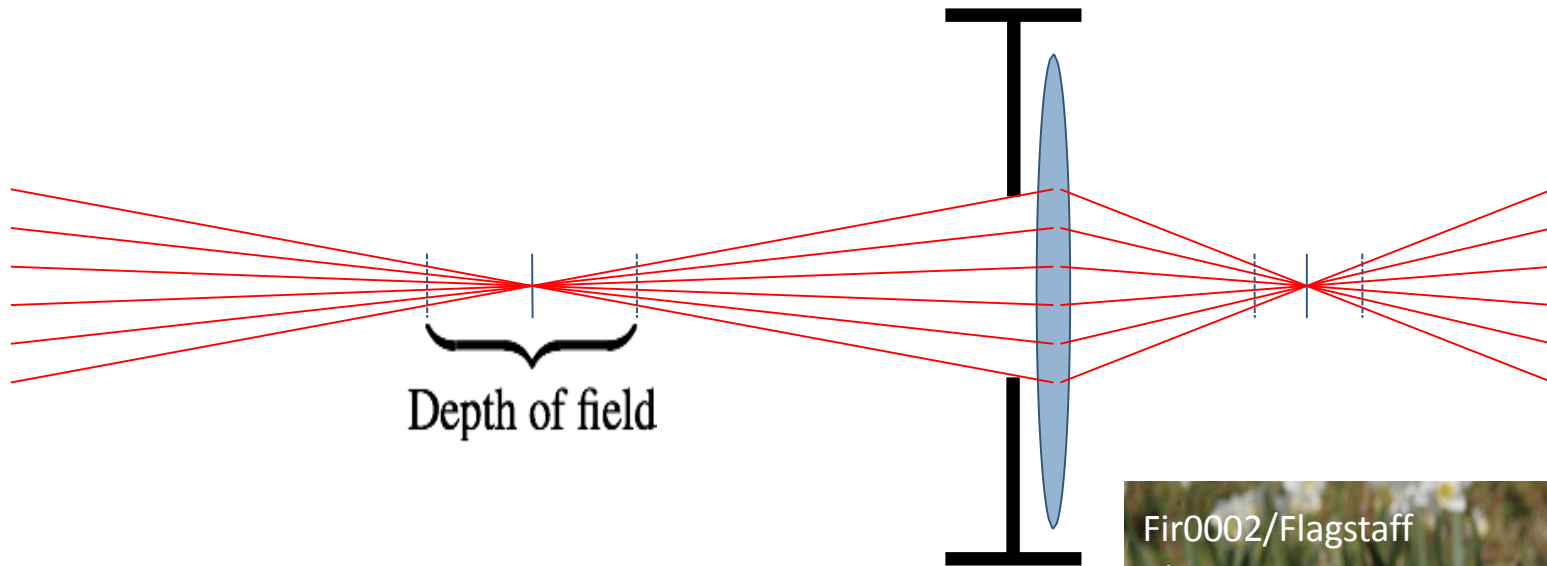


Profondeur de
champ étroite



Profondeur de champ – petite ouverture

Depth of field – small aperture



Petite
ouverture

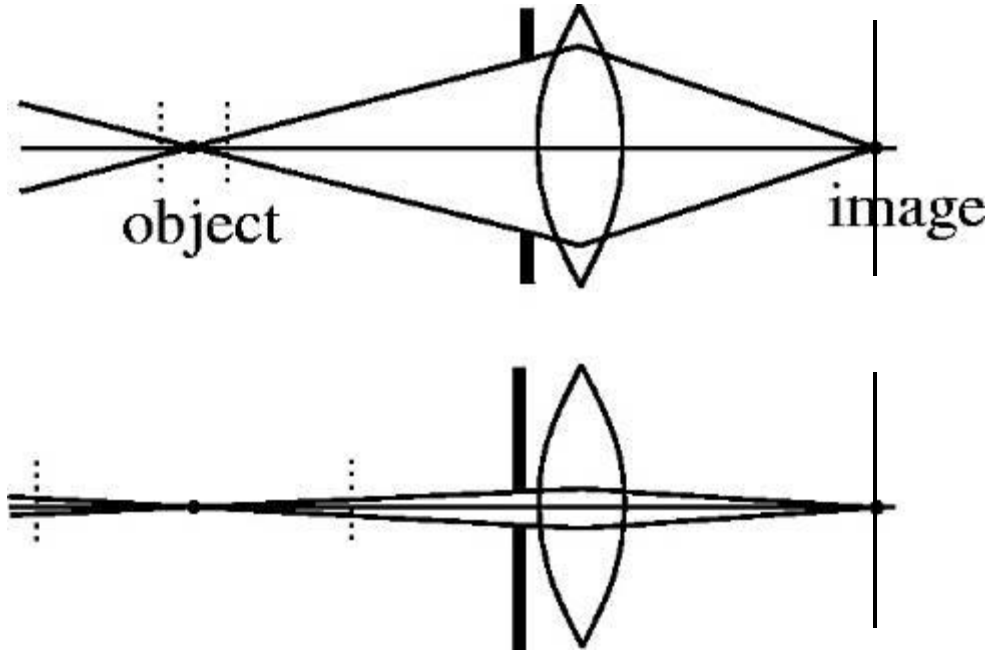


Large
profondeur de
champ

Ouverture trop petite produit une *diffraction*
d'où une *perte de la netteté*,

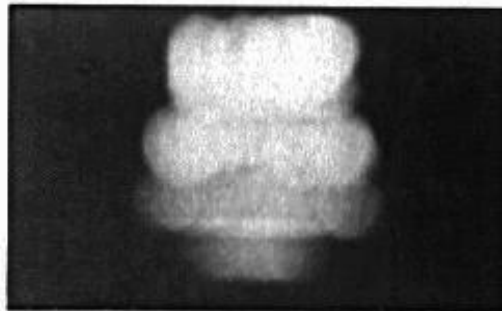


Comment peut-on contrôler la profondeur de champ?

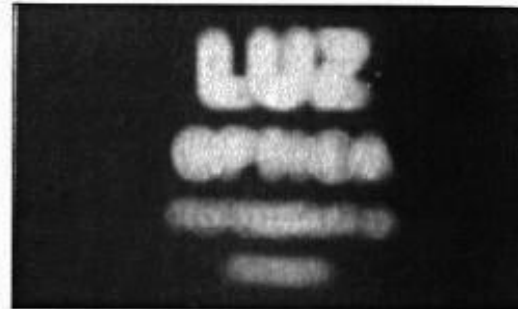


- Changing the aperture size affects depth of field
 - A smaller aperture increases the range in which the object is approximately in focus
 - But small aperture reduces amount of light – need to increase exposure

Shrinking the aperture



2 mm



1 mm



0.6mm



0.35 mm

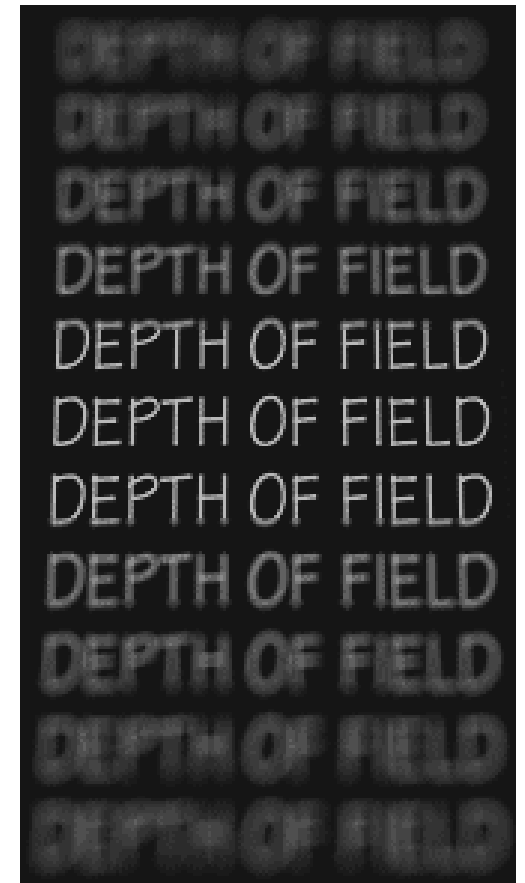


0.15 mm



0.07 mm

Profondeur de mise au point (Depth of Field)



<http://www.cambridgeincolour.com/tutorials/depth-of-field.htm>

A close-up photograph of the front of a vintage Retinette camera. The camera has a silver-colored metal body. The lens is a large, multi-element lens with a black barrel. The lens mount is visible, showing the text "Reomar - Kreuznach" and "Zeiss". The lens is surrounded by a silver-colored ring with various markings, including "f/2.5", "f/3.5", "f/5", "f/8", "f/11", "f/16", "f/22", "f/28", "f/35", "f/45", "f/56", "f/63", "f/71", "f/80", "f/90", "f/100", "f/110", "f/125", "f/140", "f/160", "f/180", "f/200", "f/225", "f/250", "f/280", "f/315", "f/360", "f/400", "f/450", "f/500", "f/560", "f/630", "f/710", "f/800", "f/900", "f/1000", "f/1100", "f/1250", "f/1400", "f/1600", "f/1800", "f/2000", "f/2250", "f/2500", "f/2800", "f/3150", "f/3600", "f/4000", "f/4500", "f/5000", "f/5600", "f/6300", "f/7100", "f/8000", "f/9000", "f/10000", "f/11000", "f/12500", "f/14000", "f/16000", "f/18000", "f/20000", "f/22500", "f/25000", "f/28000", "f/31500", "f/36000", "f/40000", "f/45000", "f/50000", "f/56000", "f/63000", "f/71000", "f/80000", "f/90000", "f/100000", "f/110000", "f/125000", "f/140000", "f/160000", "f/180000", "f/200000", "f/225000", "f/250000", "f/280000", "f/315000", "f/360000", "f/400000", "f/450000", "f/500000", "f/560000", "f/630000", "f/710000", "f/800000", "f/900000", "f/1000000", "f/1100000", "f/1250000", "f/1400000", "f/1600000", "f/1800000", "f/2000000", "f/2250000", "f/2500000", "f/2800000", "f/3150000", "f/3600000", "f/4000000", "f/4500000", "f/5000000", "f/5600000", "f/6300000", "f/7100000", "f/8000000", "f/9000000", "f/10000000", "f/11000000", "f/12500000", "f/14000000", "f/16000000", "f/18000000", "f/20000000", "f/22500000", "f/25000000", "f/28000000", "f/31500000", "f/36000000", "f/40000000", "f/45000000", "f/50000000", "f/56000000", "f/63000000", "f/71000000", "f/80000000", "f/90000000", "f/100000000", "f/110000000", "f/125000000", "f/140000000", "f/160000000", "f/180000000", "f/200000000", "f/225000000", "f/250000000", "f/280000000", "f/315000000", "f/360000000", "f/400000000", "f/450000000", "f/500000000", "f/560000000", "f/630000000", "f/710000000", "f/800000000", "f/900000000", "f/1000000000", "f/1100000000", "f/1250000000", "f/1400000000", "f/1600000000", "f/1800000000", "f/2000000000", "f/2250000000", "f/2500000000", "f/2800000000", "f/3150000000", "f/3600000000", "f/4000000000", "f/4500000000", "f/5000000000", "f/5600000000", "f/6300000000", "f/7100000000", "f/8000000000", "f/9000000000", "f/10000000000", "f/11000000000", "f/12500000000", "f/14000000000", "f/16000000000", "f/18000000000", "f/20000000000", "f/22500000000", "f/25000000000", "f/28000000000", "f/31500000000", "f/36000000000", "f/40000000000", "f/45000000000", "f/50000000000", "f/56000000000", "f/63000000000", "f/71000000000", "f/80000000000", "f/90000000000", "f/100000000000", "f/110000000000", "f/125000000000", "f/140000000000", "f/160000000000", "f/180000000000", "f/200000000000", "f/225000000000", "f/250000000000", "f/280000000000", "f/315000000000", "f/360000000000", "f/400000000000", "f/450000000000", "f/500000000000", "f/560000000000", "f/630000000000", "f/710000000000", "f/800000000000", "f/900000000000", "f/1000000000000", "f/1100000000000", "f/1250000000000", "f/1400000000000", "f/1600000000000", "f/1800000000000", "f/2000000000000", "f/2250000000000", "f/2500000000000", "f/2800000000000", "f/3150000000000", "f/3600000000000", "f/4000000000000", "f/4500000000000", "f/5000000000000", "f/5600000000000", "f/6300000000000", "f/7100000000000", "f/8000000000000", "f/9000000000000", "f/10000000000000", "f/11000000000000", "f/12500000000000", "f/14000000000000", "f/16000000000000", "f/18000000000000", "f/20000000000000", "f/22500000000000", "f/25000000000000", "f/28000000000000", "f/31500000000000", "f/36000000000000", "f/40000000000000", "f/45000000000000", "f/50000000000000", "f/56000000000000", "f/63000000000000", "f/71000000000000", "f/80000000000000", "f/90000000000000", "f/100000000000000", "f/110000000000000", "f/125000000000000", "f/140000000000000", "f/160000000000000", "f/180000000000000", "f/200000000000000", "f/225000000000000", "f/250000000000000", "f/280000000000000", "f/315000000000000", "f/360000000000000", "f/400000000000000", "f/450000000000000", "f/500000000000000", "f/560000000000000", "f/630000000000000", "f/710000000000000", "f/800000000000000", "f/900000000000000", "f/1000000000000000", "f/1100000000000000", "f/1250000000000000", "f/1400000000000000", "f/1600000000000000", "f/1800000000000000", "f/2000000000000000", "f/2250000000000000", "f/2500000000000000", "f/2800000000000000", "f/3150000000000000", "f/3600000000000000", "f/4000000000000000", "f/4500000000000000", "f/5000000000000000", "f/5600000000000000", "f/6300000000000000", "f/7100000000000000", "f/8000000000000000", "f/9000000000000000", "f/10000000000000000", "f/11000000000000000", "f/12500000000000000", "f/14000000000000000", "f/16000000000000000", "f/18000000000000000", "f/200000

Lentille à distance focale fixe

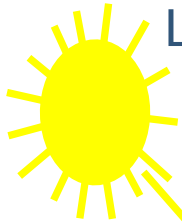


• Lentille à Zoom (distance focale variable)

Capture d'image

Source de lumière

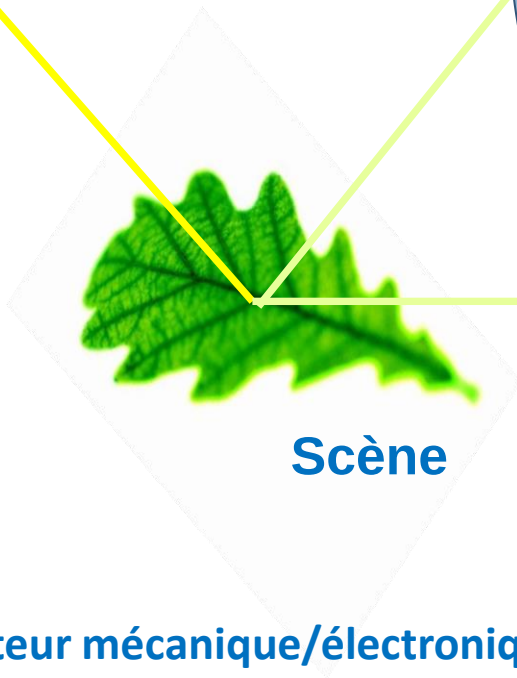
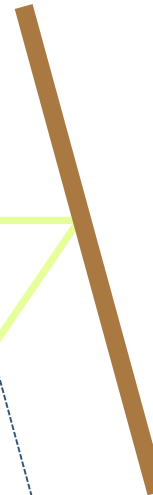
Light source



Obturbateur

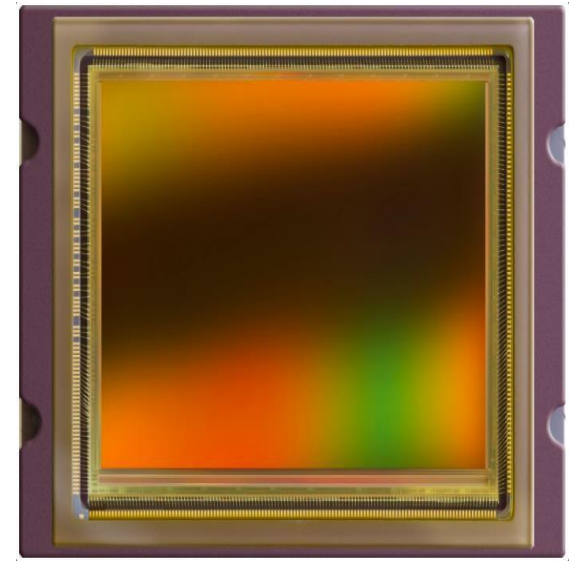
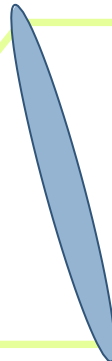
Shutter

Détecteur

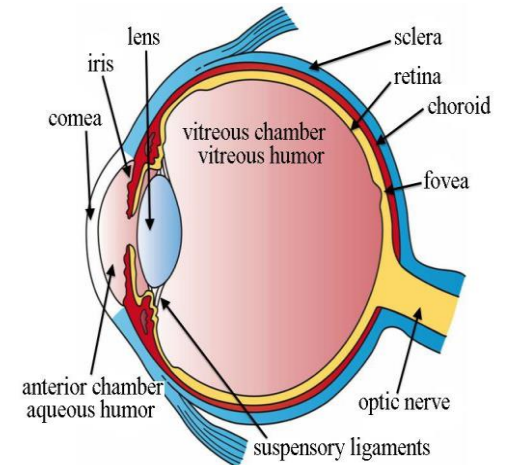


Scène

Système d'imagerie
(Caméra)



CMOS image sensor
(CMOSIS 48Mp)



Obturbateur mécanique/électronique

Image Numérique

Digital image



$j \rightarrow$

$i \downarrow$

255	255	255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255	255	255
255	255	255	0	0	255	255	255	255	255
255	255	255	0	0	85	255	255	255	255
255	255	0	85	85	0	255	255	255	255
255	255	0	85	85	170	170	255	255	255
255	85	85	0	170	170	85	85	255	255
255	255	170	170	85	85	85	255	255	255
255	255	255	255	255	255	255	255	255	255
255	255	255	255	255	255	255	255	255	255

$image(i, j)$

Images Couleur

Colour images



RGB colour
image

Red



Green



Blue



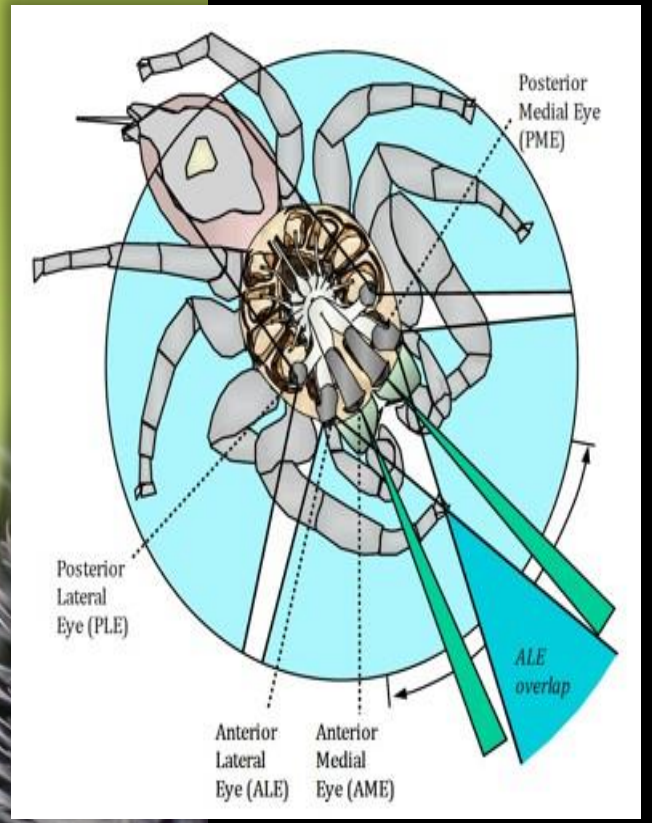
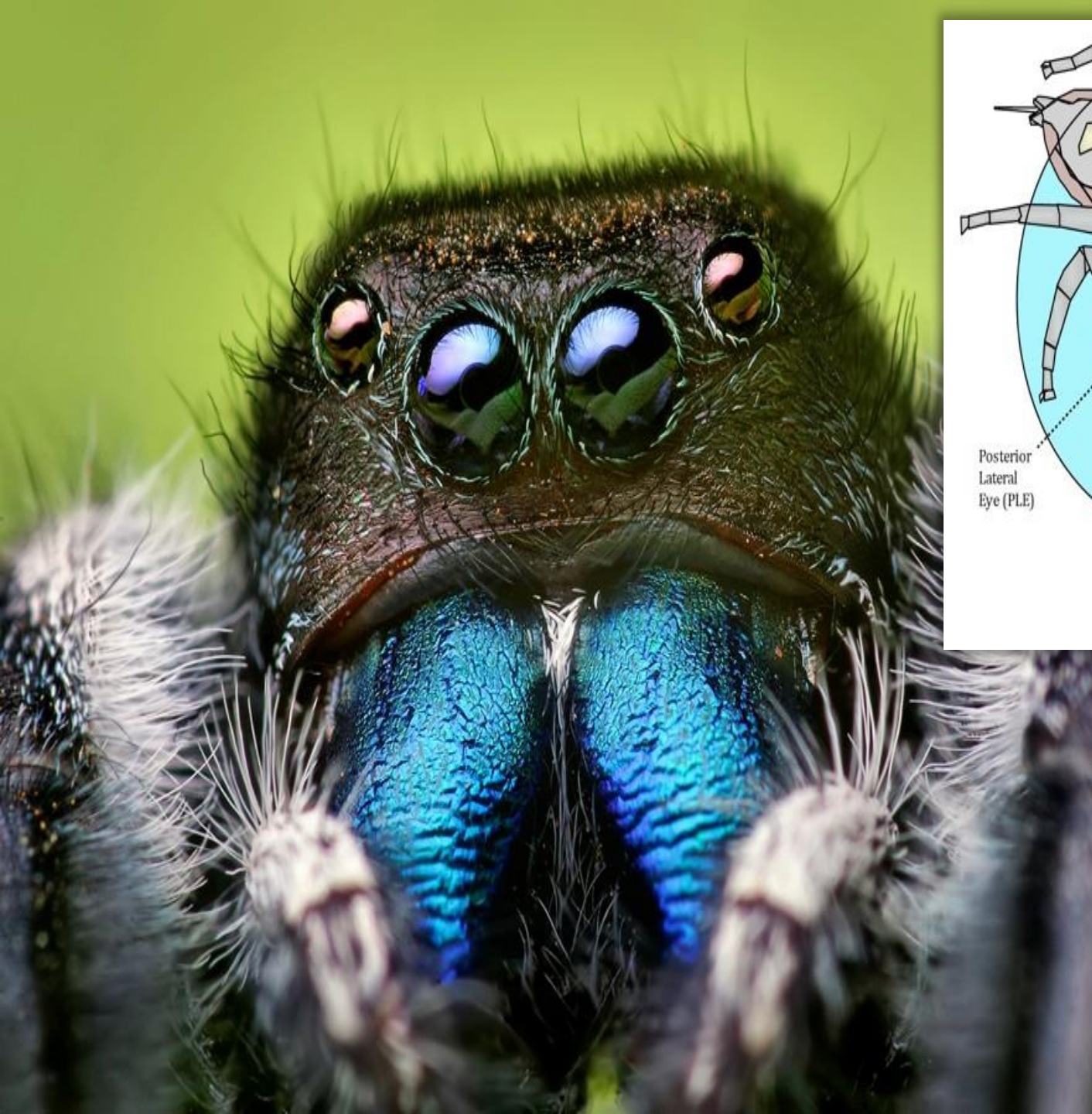
Quelques exemples de systèmes visuels biologiques



nautilus eye, wikipedia





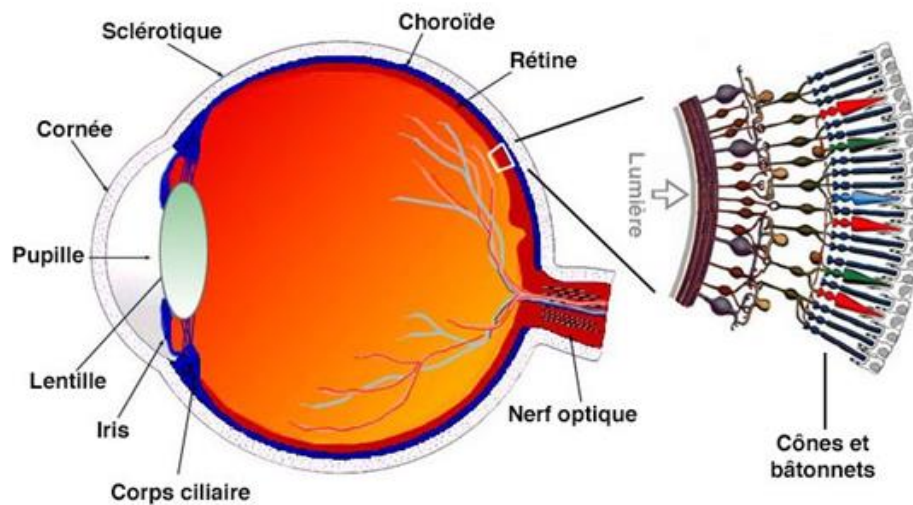




Vision Humaine

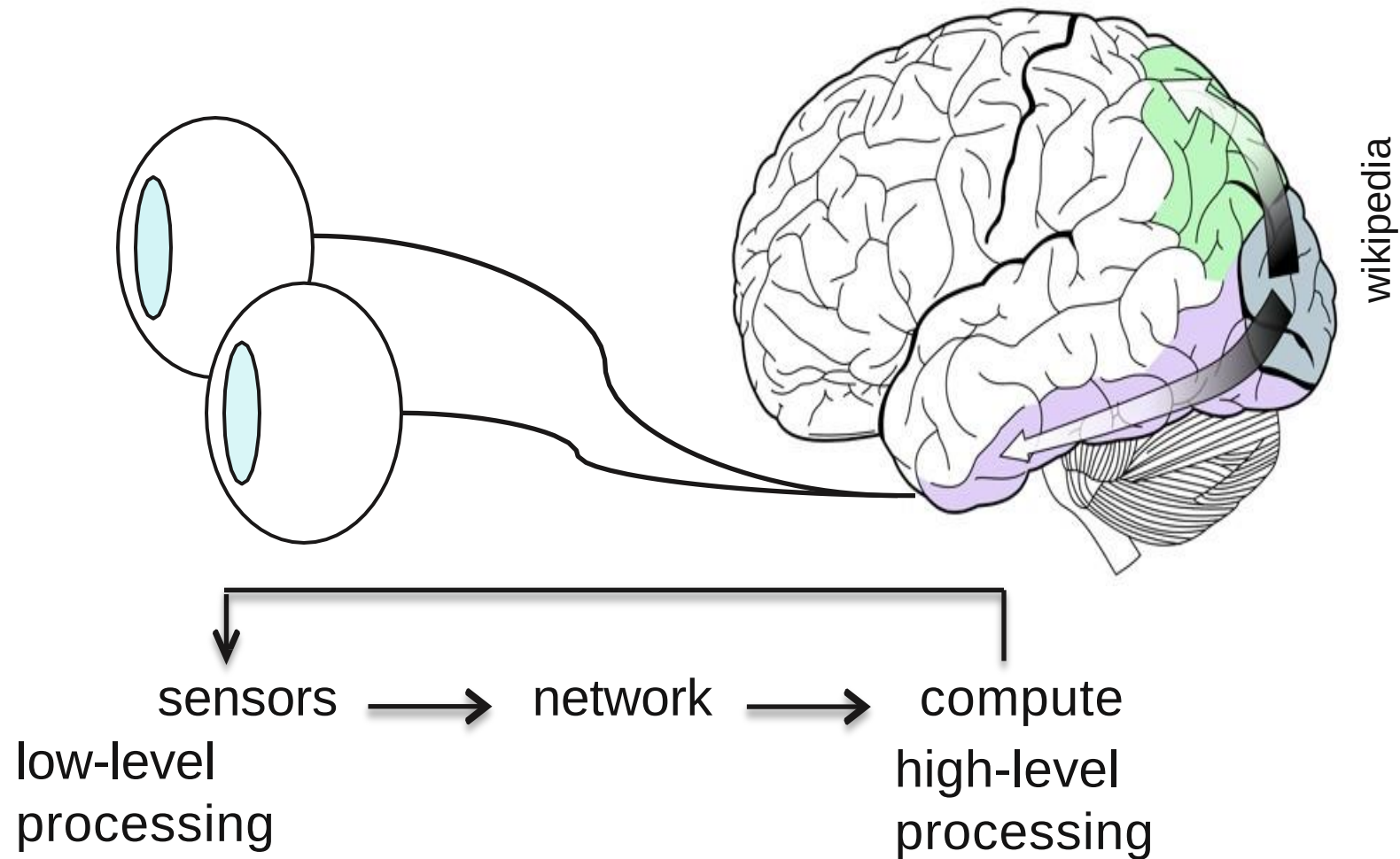
Perception visuelle humaine

La lumière pénètre dans l'œil par un orifice circulaire situé au centre de l'iris, la pupille. Elle traverse ensuite le cristallin qui sert d'objectif et projette sur la rétine une image renversée des objets situés devant l'œil. La lumière est convertie en message électrique par la multitude de cellules photosensibles qui est ensuite véhiculé par le nerf optique vers le cerveau.

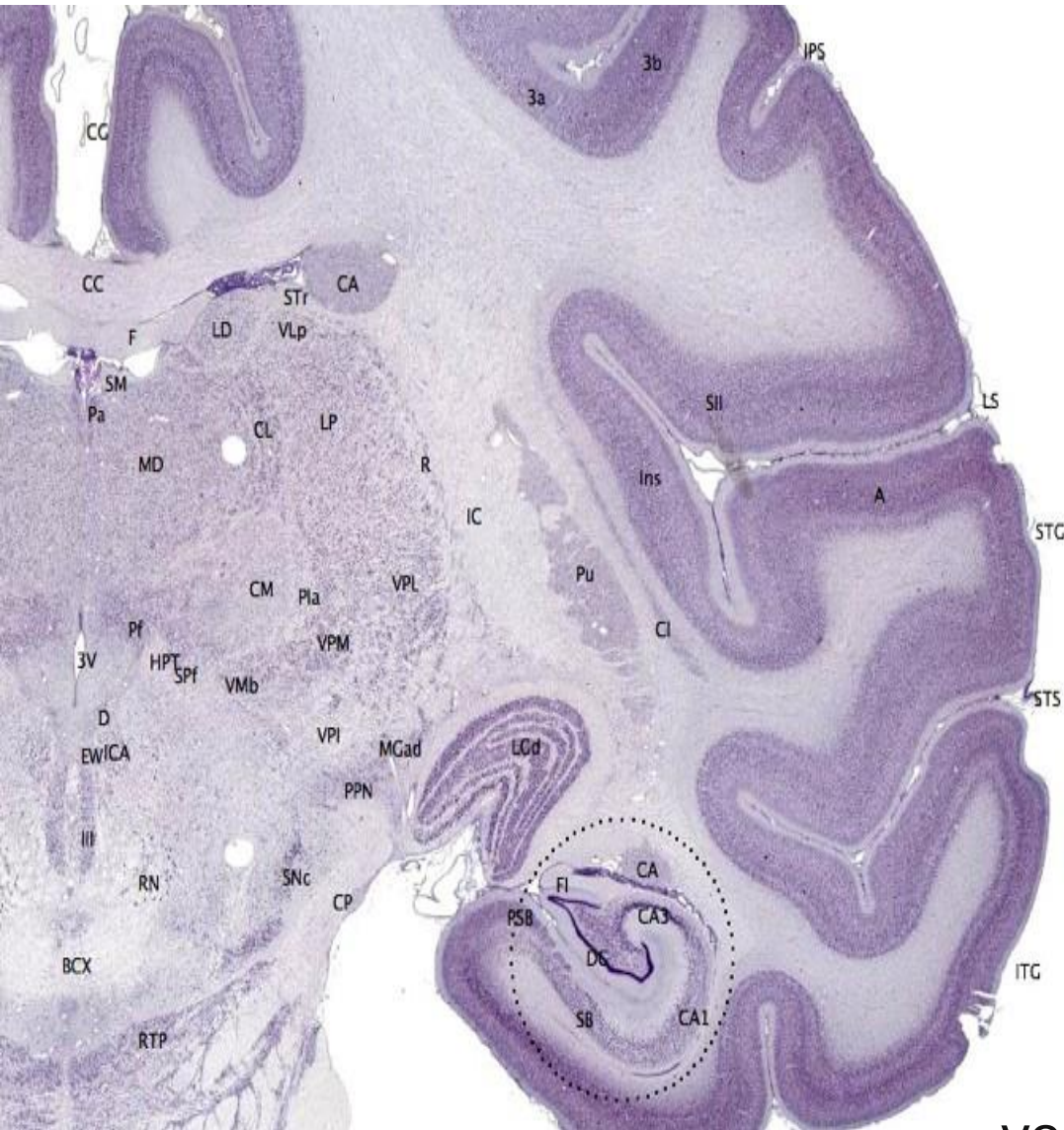


Système visuel humain

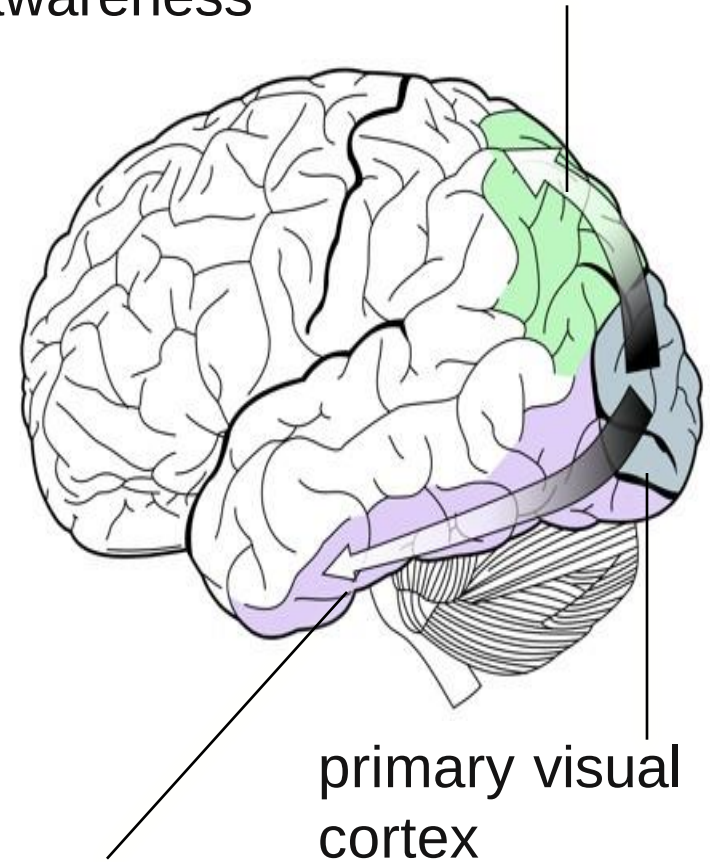
Aperçu



Aperçu



dorsal stream: spatial awareness



ventral stream:
recognition, object identification

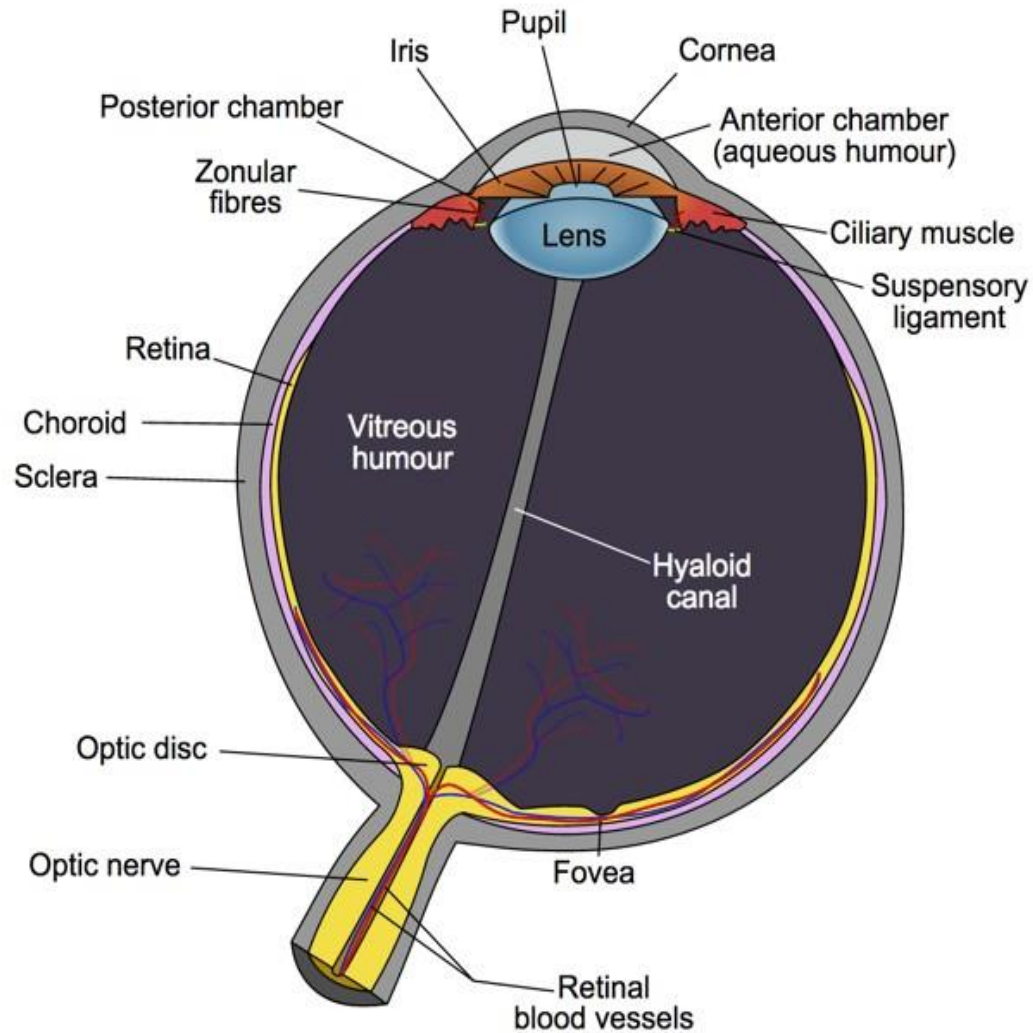
Illusion Optique :



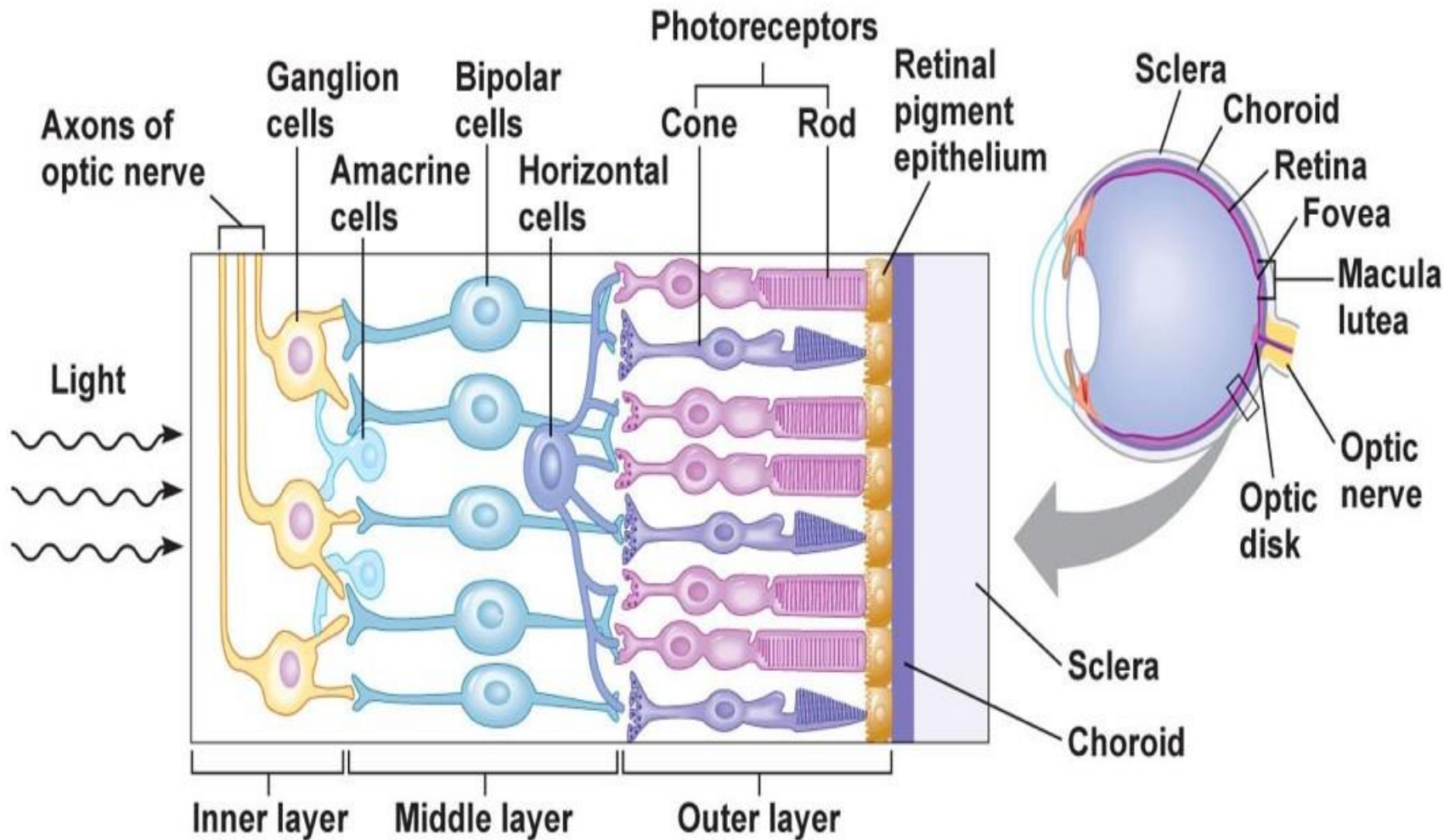
Illusion Optique : Très difficile à interpréter par un ordinateur



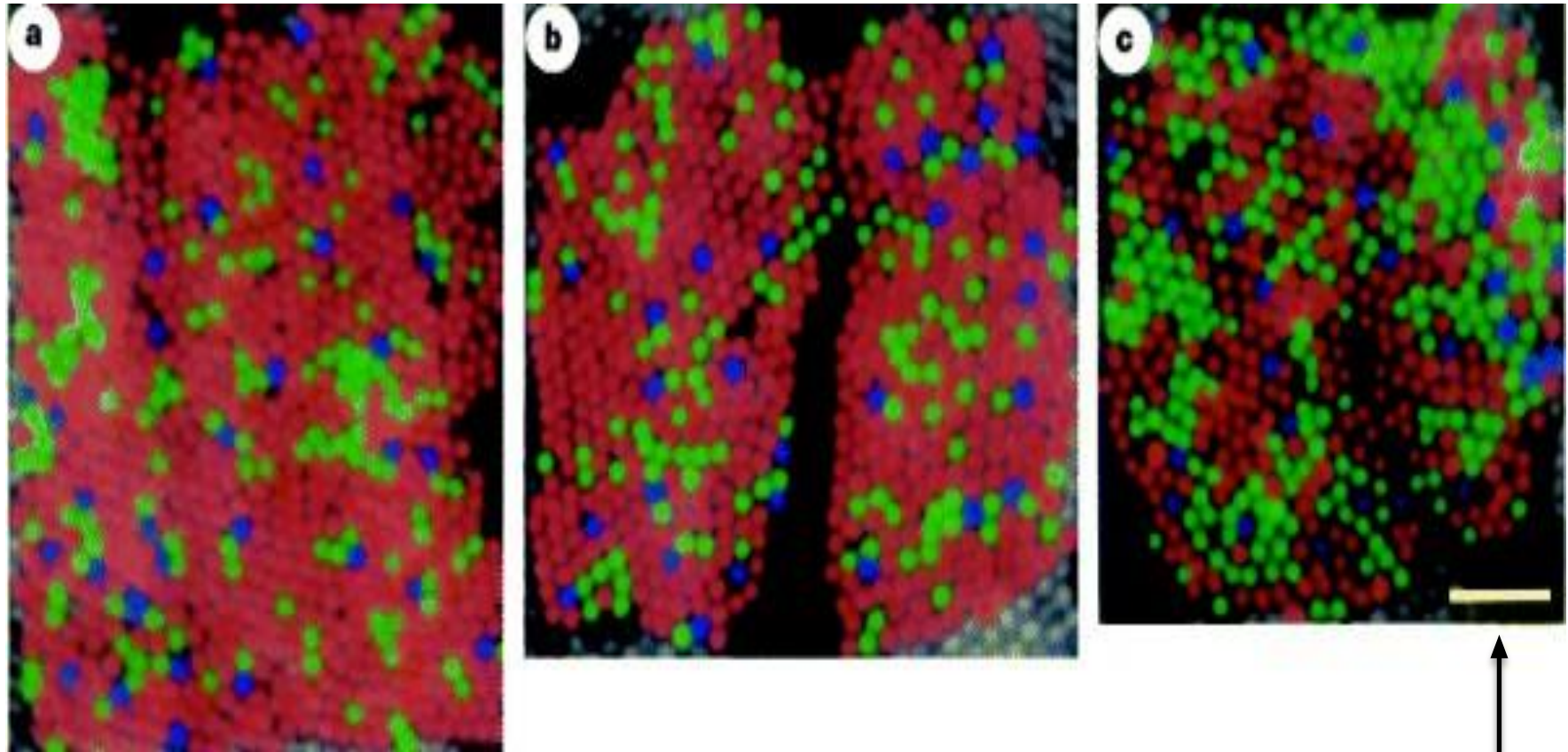
Anatomie de l'œil humain



The Retina

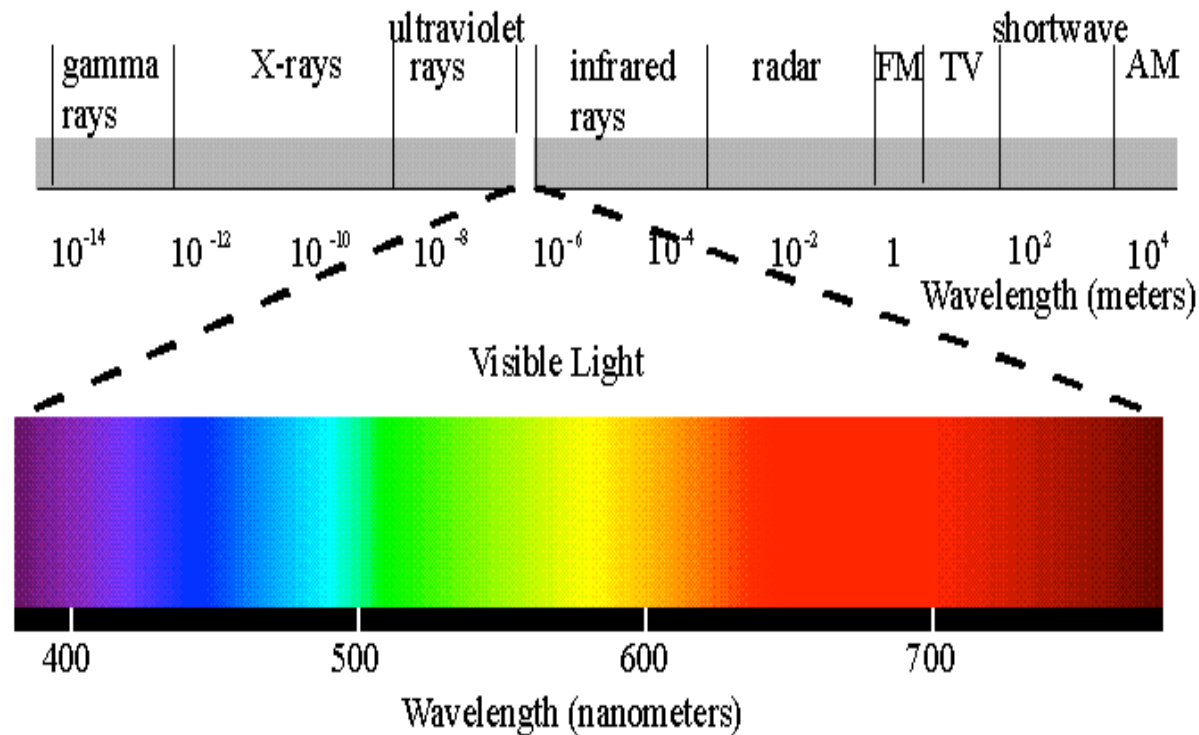


The Retina

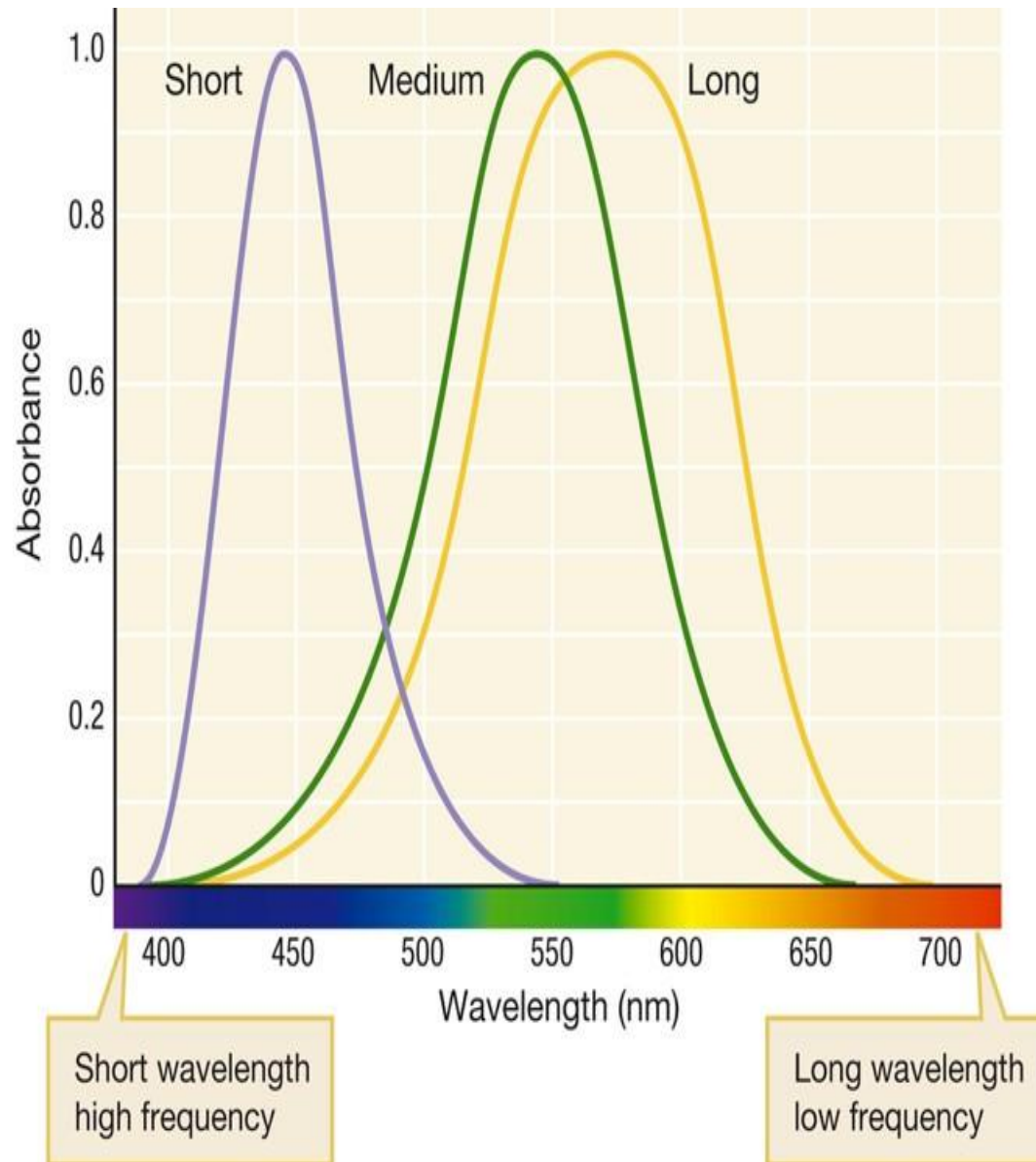


5 arcmin visual
angle

Perception de la Couleur



Color Perception - Sensibilité des Cones



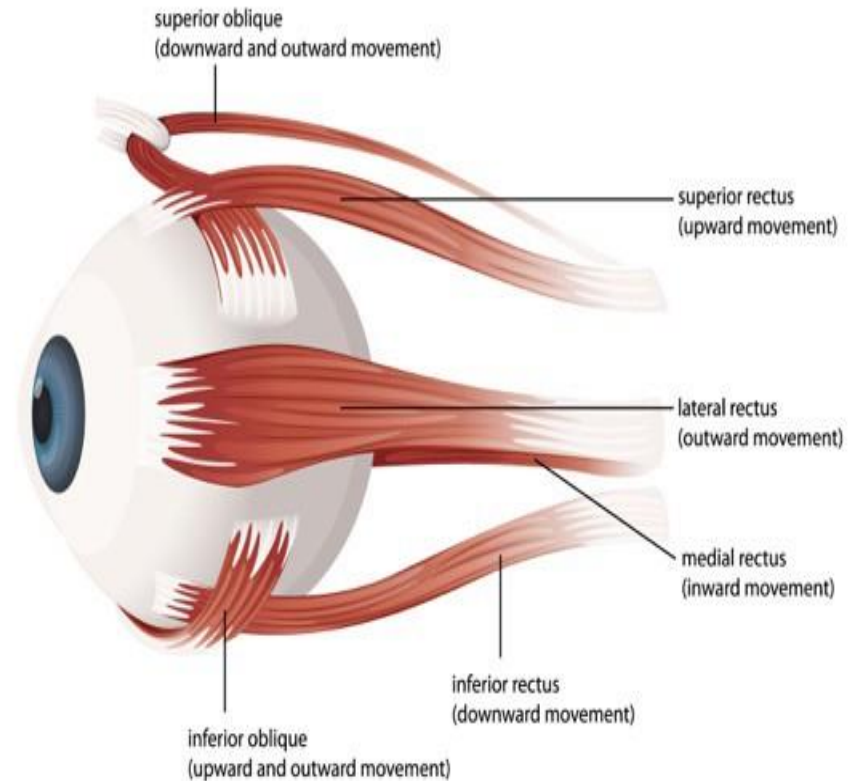
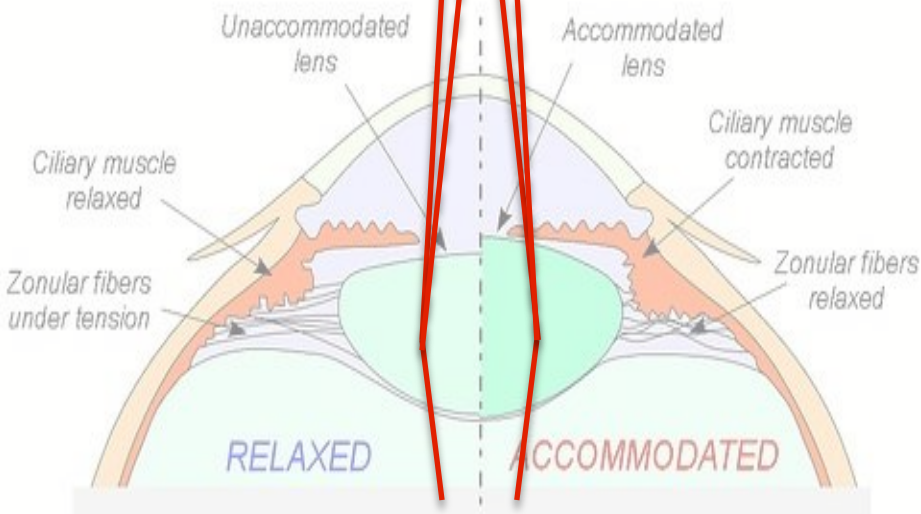
Oculomotor Processes

far focus →

16 years: ~8cm to ∞

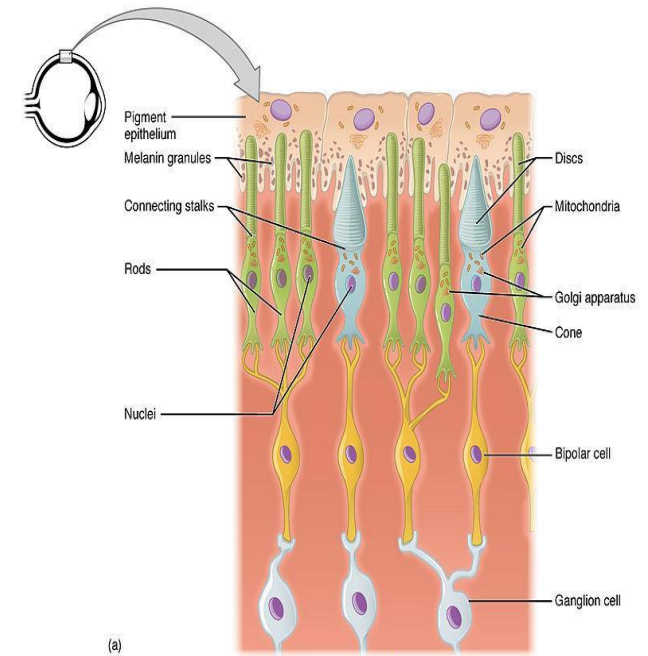
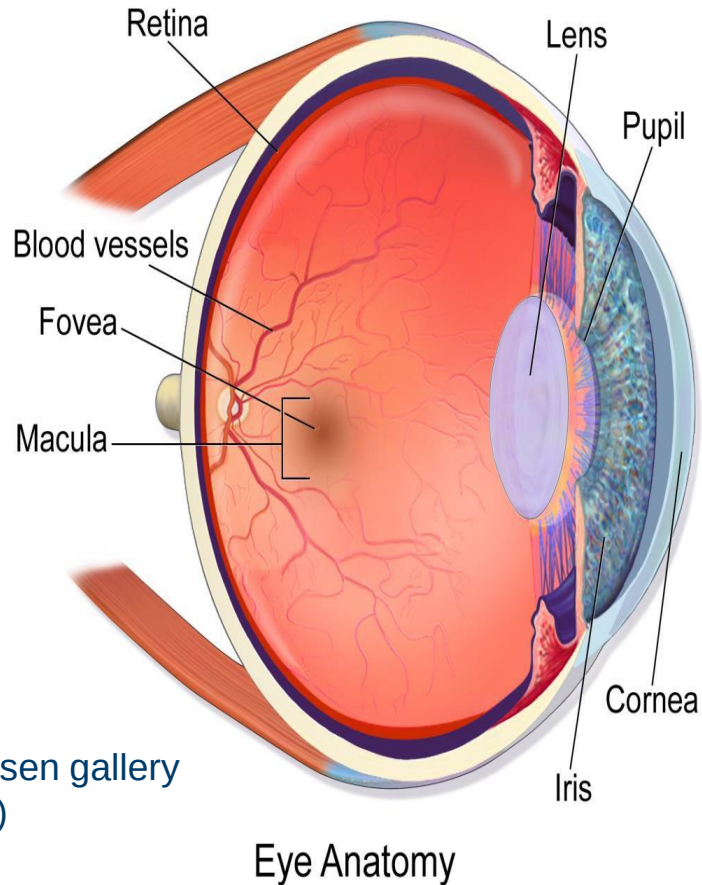
50 years: ~50cm to ∞ (mostly irrelevant)

near focus →

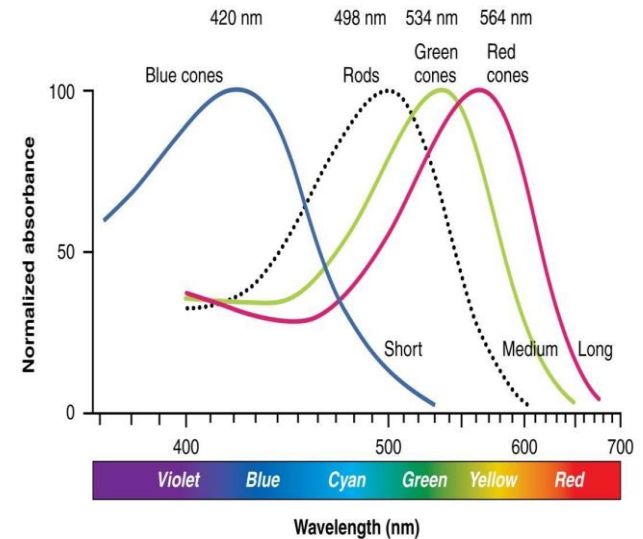


Vision Humaine

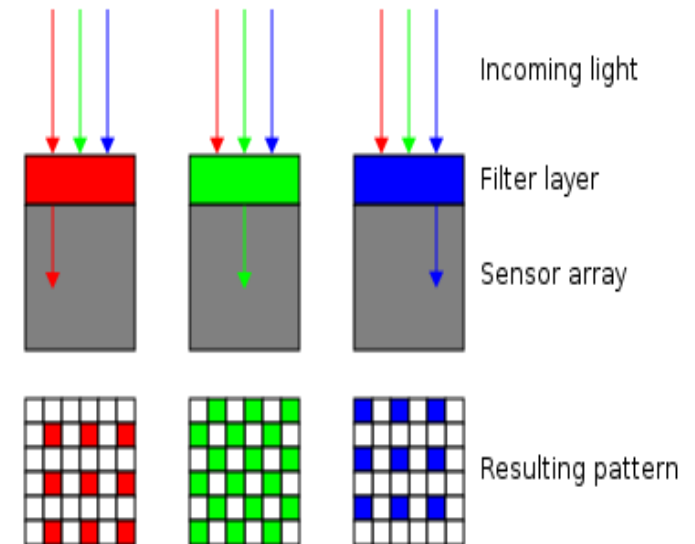
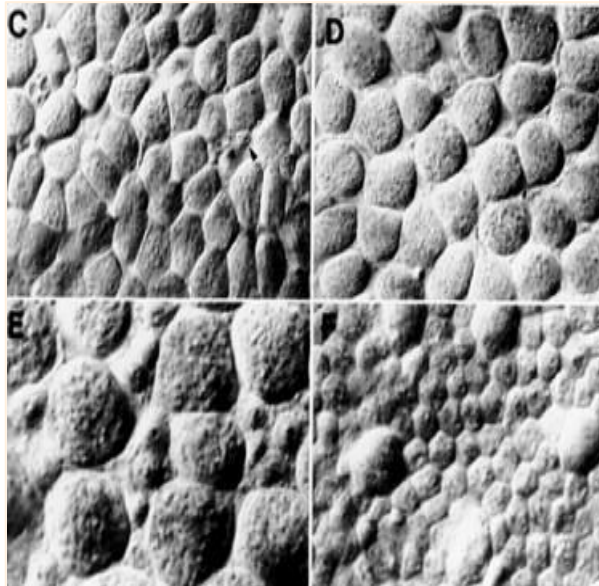
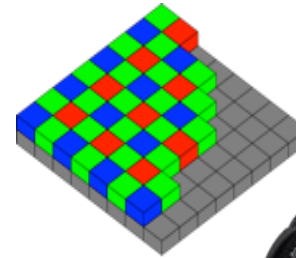
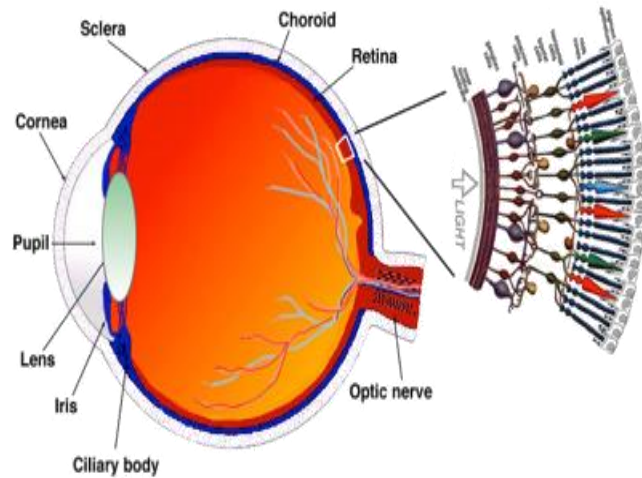
Human Vision



(OpenStax College - Anatomy & Physiology)



Oeil vs Caméra



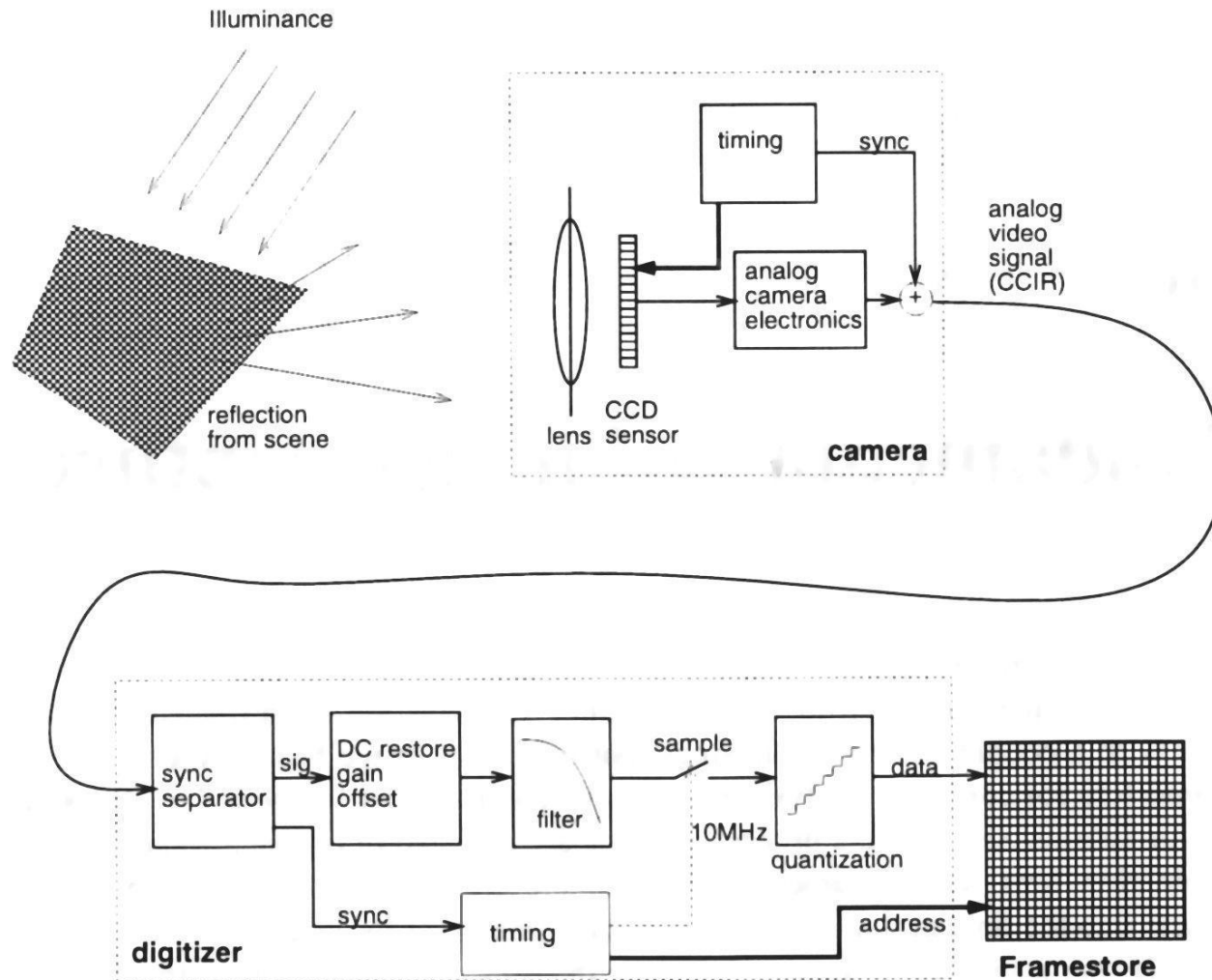
Une autre illusion optique



Cameras & Formation d'Image



Numérisation d'images



Synoptique générale de l'acquisition d'images

- optics
- aperture
- depth of field
- field of view
- sensors
- color filter arrays

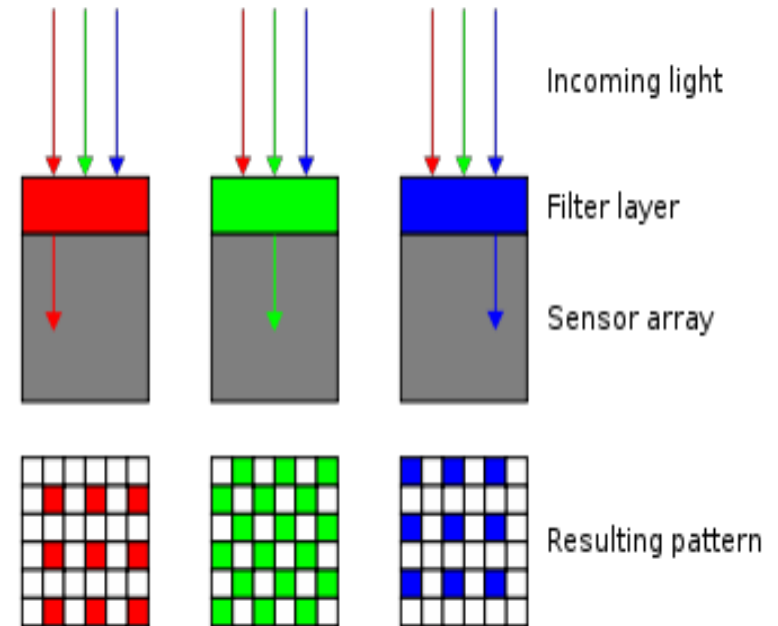
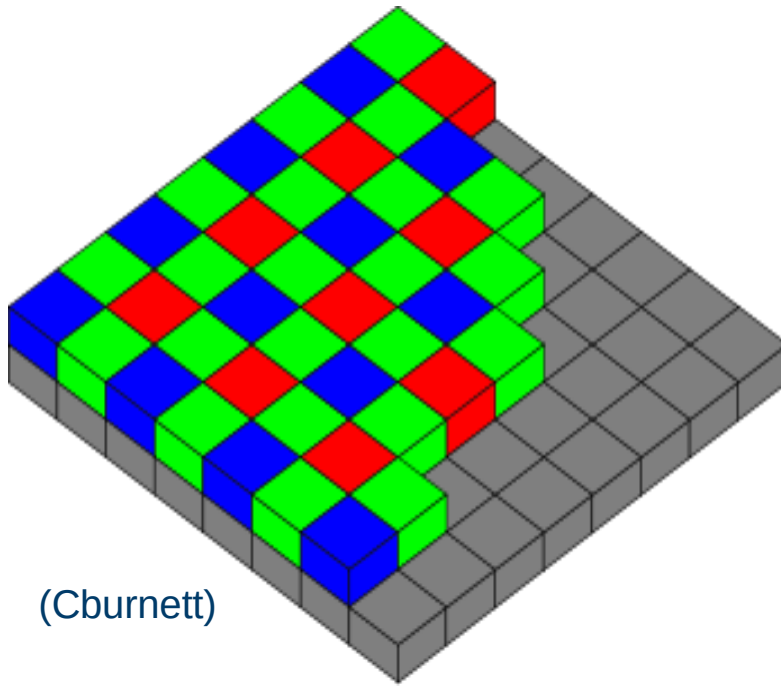


Video d'assemblage d'une caméra Canon



Détection de la Couleur dans les caméras numériques – Filtre de Bayer

Colour Sensing in digital cameras
- Bayer filter



Undersampled (incomplete) colour
information

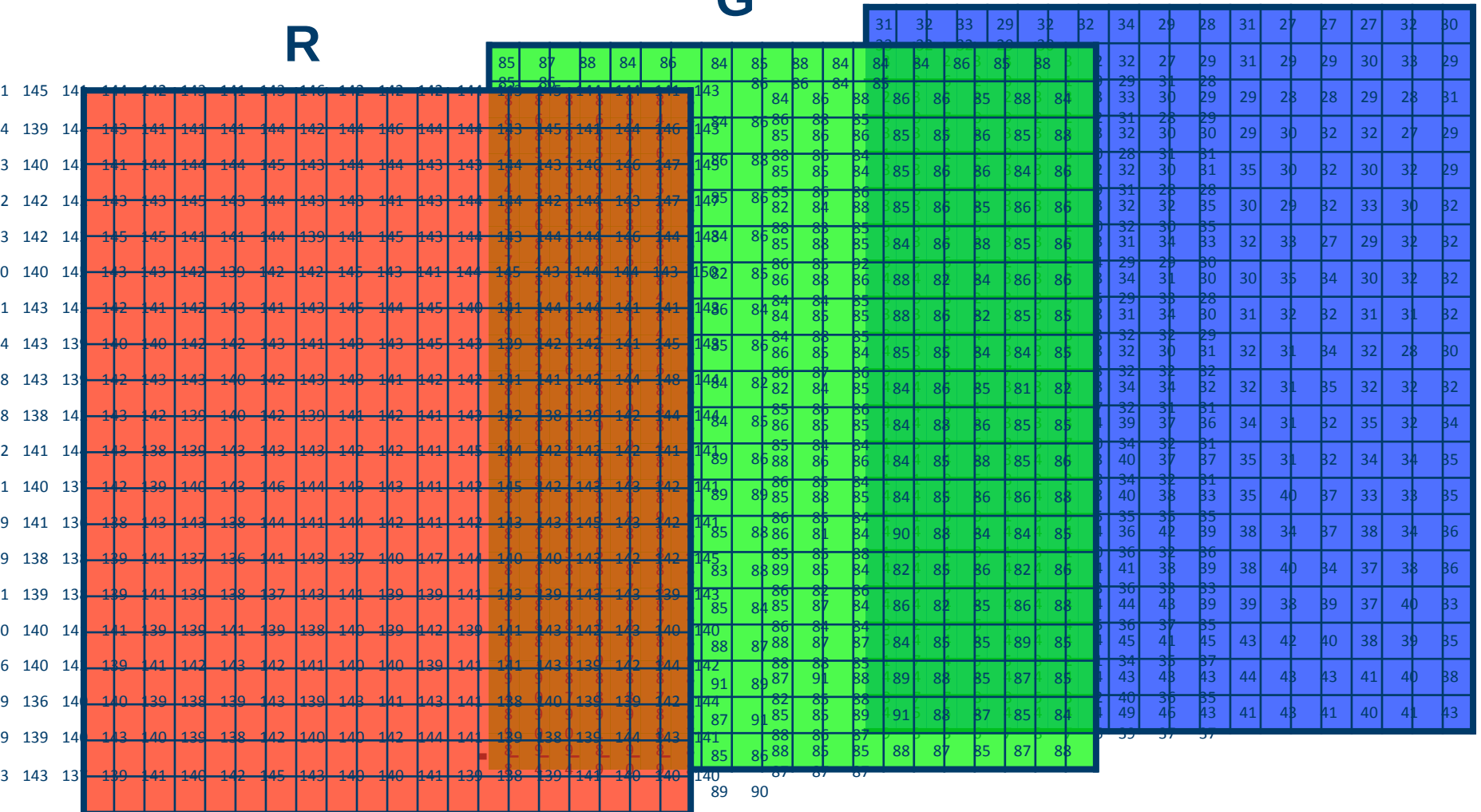
Représentation numérique des images couleur

Digital representation of colour images

B

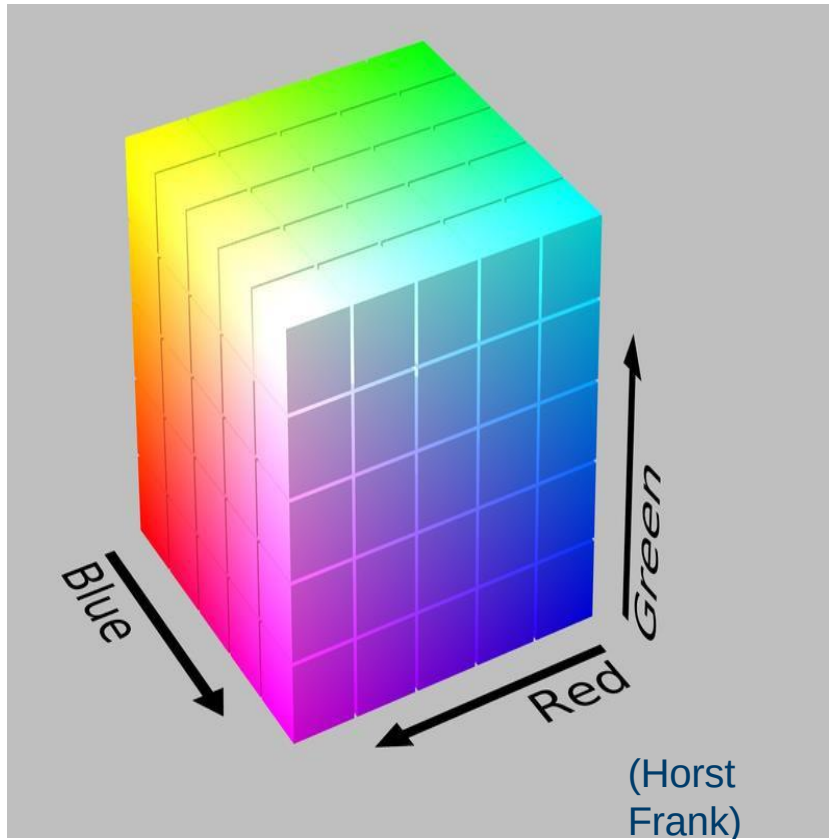
G

R



Espace des couleurs RVB

RGB colour space



Colour coordinate systems:

Normalized RGB values:

$$r = \frac{R}{R + G + B}$$

$$g = \frac{G}{R + G + B}$$

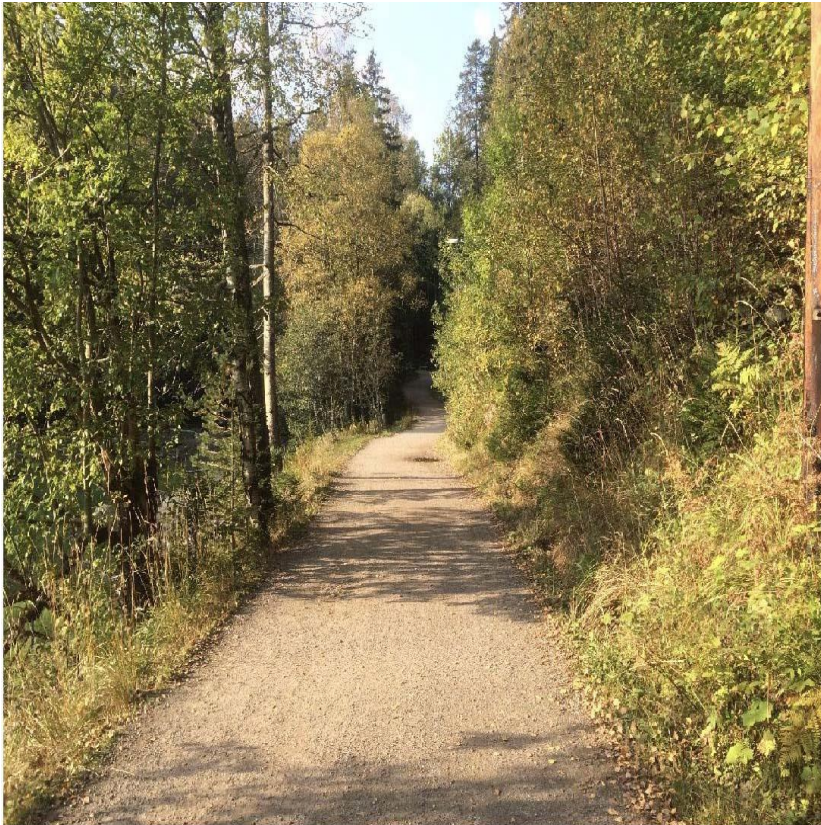
$$b = \frac{B}{R + G + B}$$

(Illumination invariance)

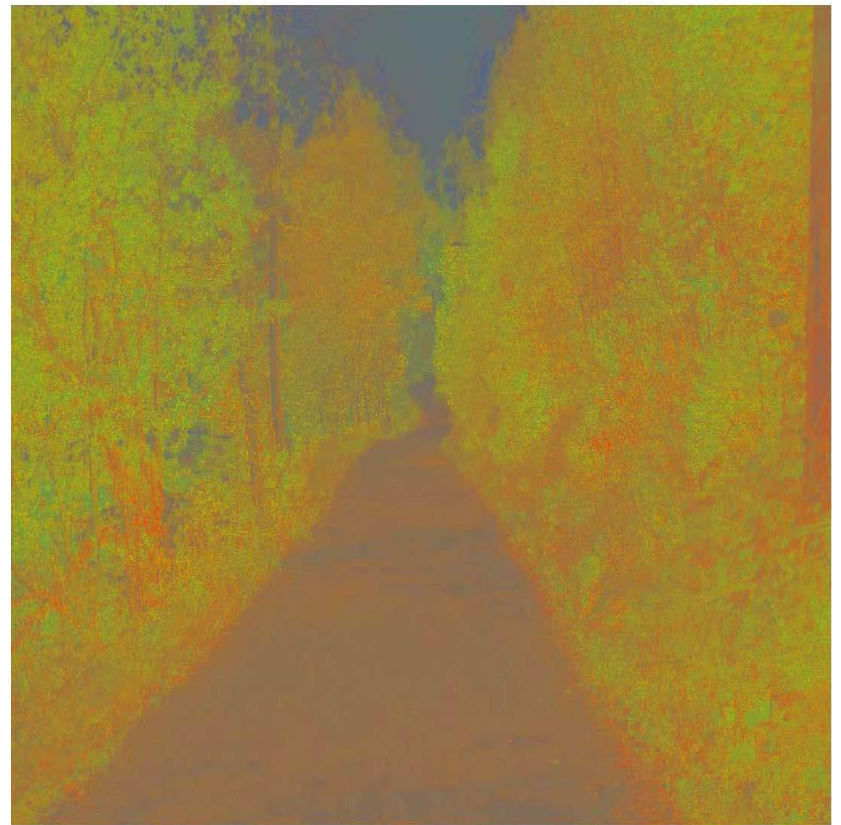
$RGB \Rightarrow XYZ \Rightarrow LAB$

Normalisation RVB (exemple)

RGB normalization (example)

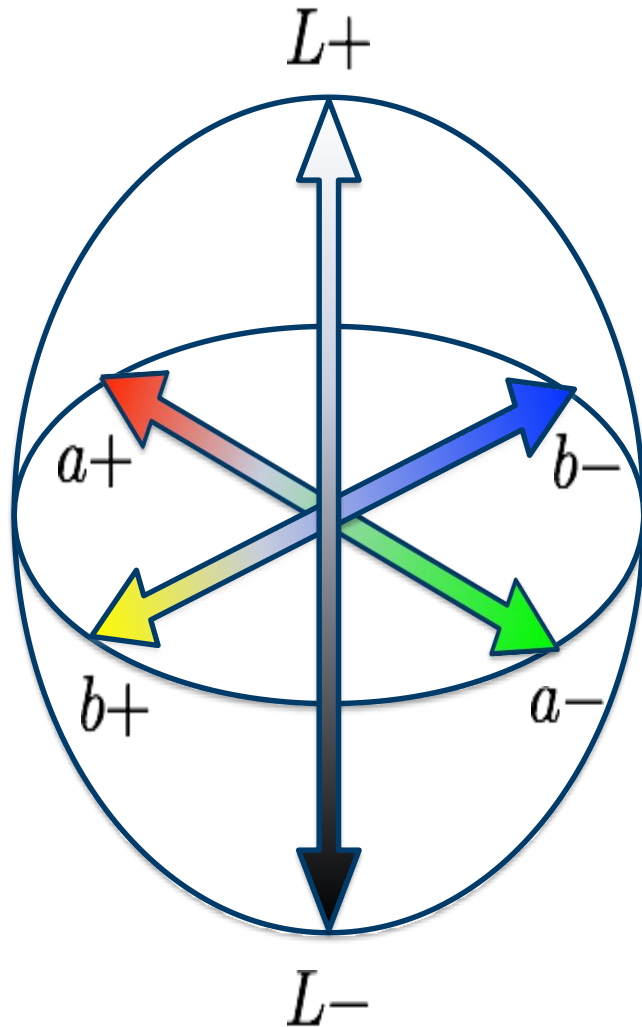


RGB
original



Normalized
RGB

Lab colour space (CIE 1976 L^* a^* b^*)

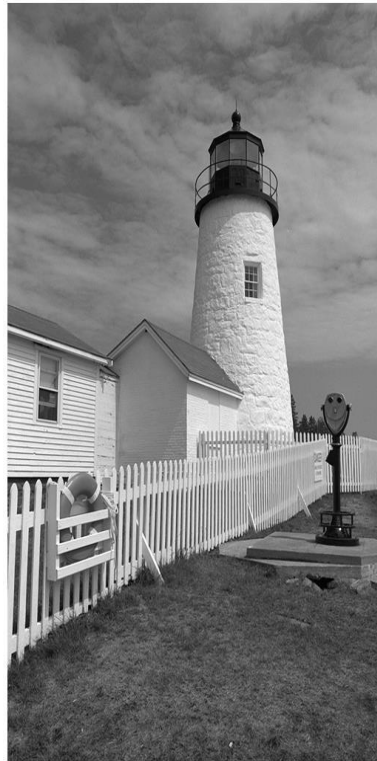


«Perceptually uniform»
colour space:

- Approximation to human vision
- L^* = Lightness (Luminosité)
- a^* , b^* = Colour opponent dimensions
- L^* = darkest black to brightest white (0 - 100)
- a^* = green to red (-100 to +100)
- b^* = blue to yellow (-100 to +100)

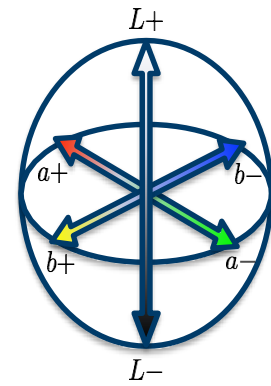
Lab - example

L

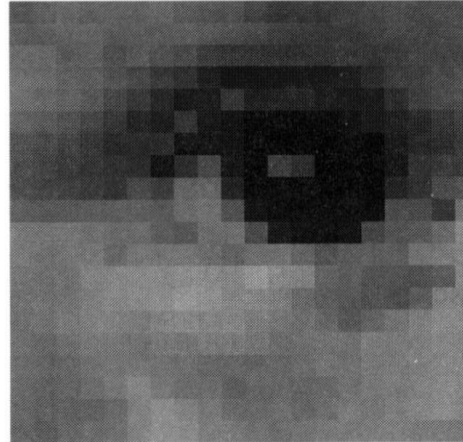


a

b



Exemple de numérisation d'une image en niveaux de gris



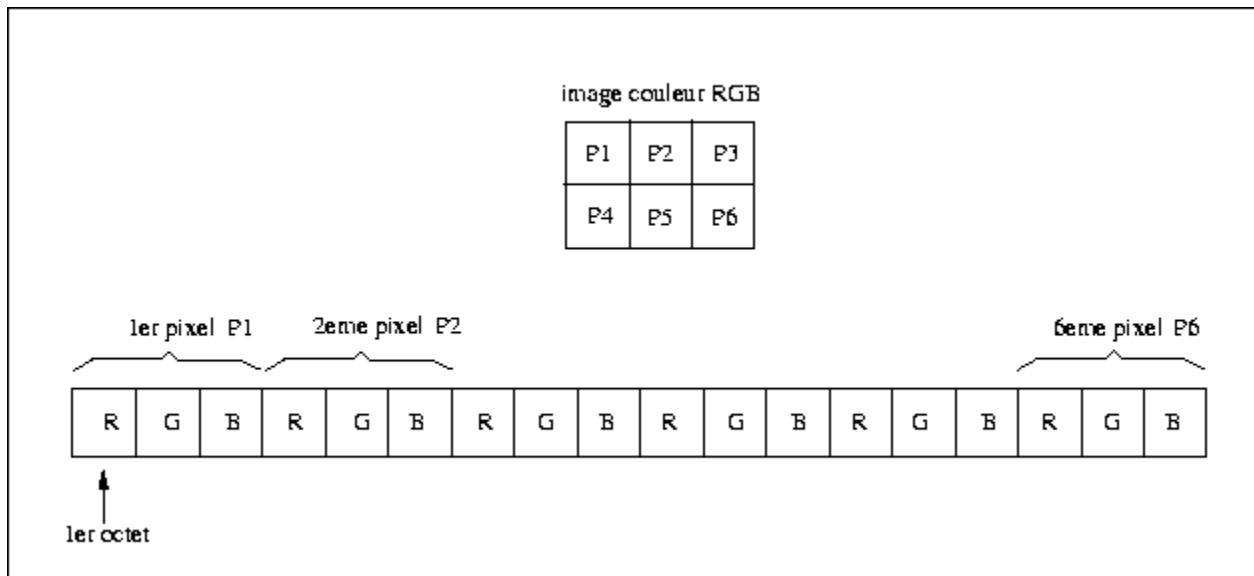
117	125	133	127	130	130	133	121	116	115	100	91	93	94	99	103	112	105	109	106
134	133	138	138	132	134	130	133	128	123	121	113	106	102	99	106	113	109	109	113
146	147	138	140	125	134	124	115	102	96	93	94	99	96	99	100	103	110	109	110
144	141	136	130	120	108	88	74	53	37	31	37	35	39	53	79	93	100	109	116
139	136	129	119	102	85	58	31	41	77	51	53	53	33	37	41	69	94	105	108
132	127	117	102	87	57	49	77	42	28	17	15	13	13	17	41	53	69	88	100
124	120	108	94	72	74	72	31	35	31	15	13	15	11	15	13	46	75	83	96
125	115	102	93	88	82	42	79	113	41	19	100	82	11	11	17	31	91	99	100
124	116	109	99	91	113	99	140	144	57	20	20	15	11	15	17	63	87	119	124
136	133	133	135	138	133	132	144	150	120	24	17	15	15	17	20	115	113	88	150
158	157	157	154	149	145	133	127	146	150	116	35	20	19	28	105	124	128	141	171
155	154	156	155	146	155	154	154	147	139	148	150	138	120	128	129	130	151	156	165
150	151	154	162	166	167	169	174	172	167	177	166	164	140	134	120	121	120	127	172
145	149	151	157	165	169	173	179	176	166	166	157	145	136	129	124	120	136	163	168
144	148	153	160	159	158	165	172	165	169	157	151	149	141	130	140	151	162	169	167
144	141	147	155	154	149	156	151	157	157	151	144	147	147	149	159	158	159	166	165
139	140	140	150	153	151	150	146	140	139	138	140	145	151	149	156	156	162	162	161
136	134	138	146	156	164	153	146	145	136	139	139	140	141	149	157	159	161	169	166
136	133	136	135	144	159	168	159	151	142	141	145	139	146	153	156	164	167	172	168
133	129	140	142	146	159	167	165	154	151	146	141	147	154	156	160	161	157	153	154

Le niveau de gris d'un pixel reflète la quantité de lumière arrivant sur une cellule CCD de la caméra : 0 => noir ; 255 => blanc (256 niveaux)

Numérisation d'une image en couleur

La plupart du temps, les pixels sont codés sur 16 bits ou 24 bits.

Pour le codage sur 24 bits, chaque canal R, G ou B contient une valeur allant de 0 à 255 (256 niveaux/canal) et les octets sont rangés en mémoire de manière séquentielle : R,G,B,R,G,B,R,G,B,...



128 251 60

=



Exemple d'une image R G,B



Image originale



Composante R



Composante G



Composante B

Le codage des couleurs

La valeur $I(i, j)$ d'un pixel $s = (i, j)$ représente son intensité lumineuse

En niveau de gris

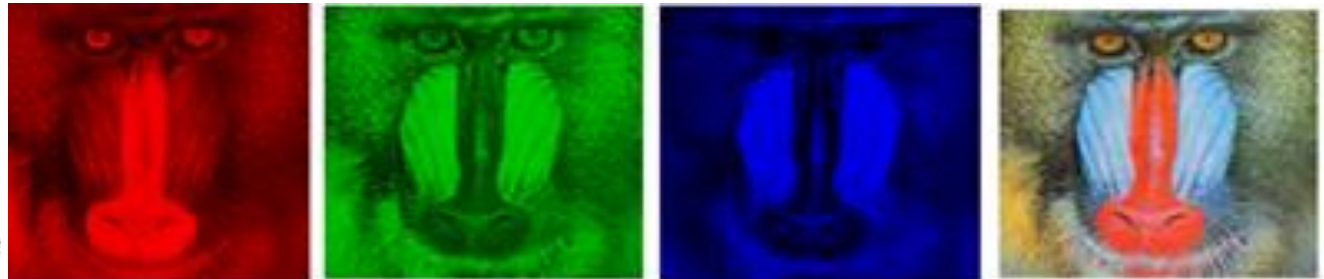
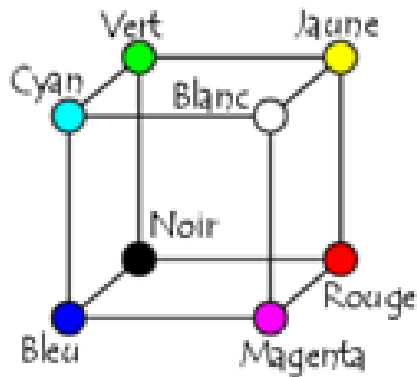
binaire : $I(i, j) = 0$ noir ou $I(i, j) = 1$ blanc

codage 8 bits : (le plus classique) $I(i, j) = 0, \dots, 255$ du plus foncé au plus clair

En couleur

codage dans l'espace RGB : trois intensités lumineuses rouge, vert, bleu.

$I_B(i, j) = 0, \dots, 255$



Le codage des couleurs ... importance de la couleur

Observez cette liste et dites la **COULEUR**
de chaque mot, pas le mot lui-même

JAUNE	BLEU	ORANGE
NOIR	ROUGE	VERT
VIOLET	JAUNE	ROUGE
ORANGE	VERT	NOIR
BLEU	ROUGE	VIOLET
VERT	BLEU	ORANGE

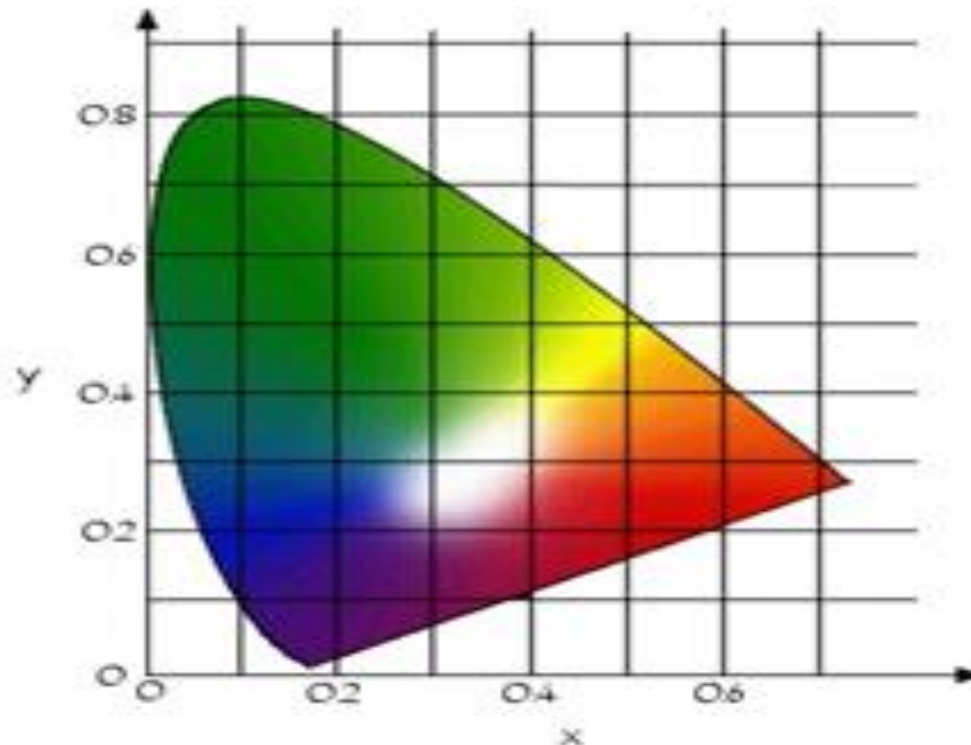
la partie droite de votre cerveau
essaye de dire la couleur
alors que la partie gauche
insiste pour lire le mot

Le codage des couleurs

l'espace Lab (espace à luminance séparée)

L : la luminance, exprimée en pourcentage (0 pour le noir 100 pour le blanc)

a et **b** deux gammes de couleur allant respectivement du vert au rouge et du bleu au jaune avec des valeurs allant de -120 +120.



Varying the aperture

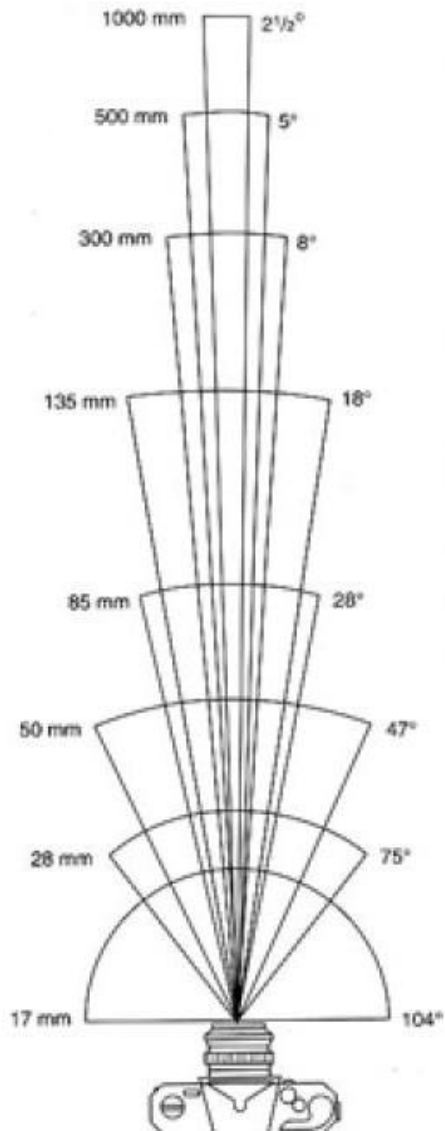


Large aperture = small DOF



Small aperture = large DOF

Field of View



17mm



28mm



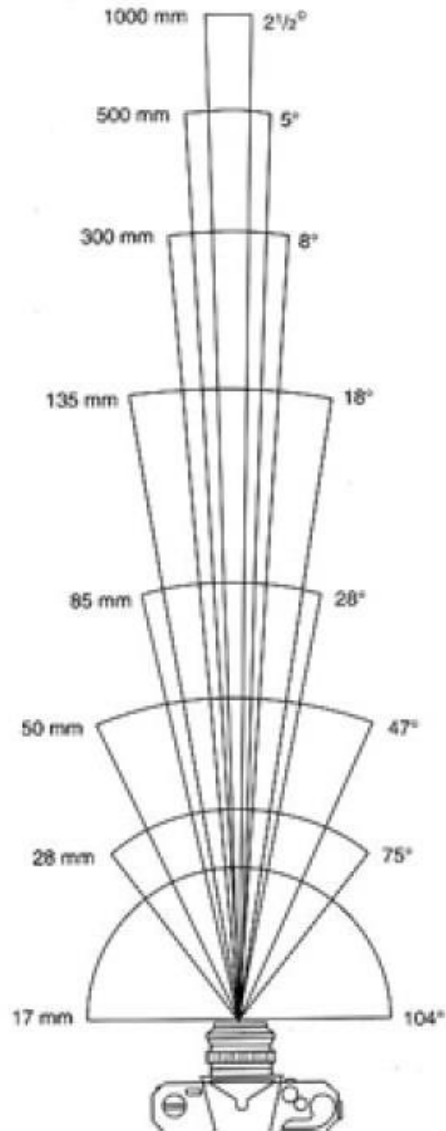
50mm



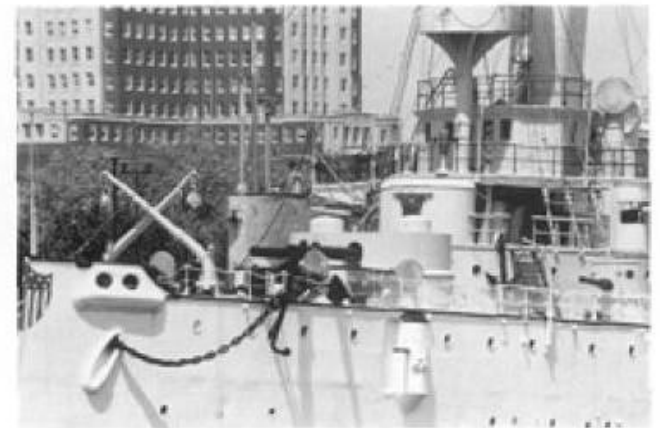
85mm

From London and Upton

Field of View



135mm



300mm



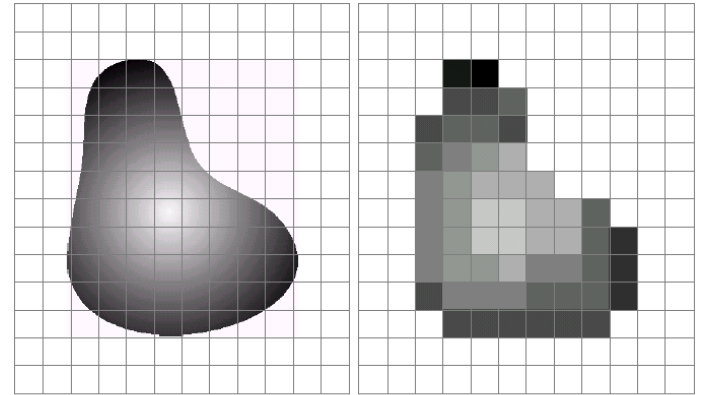
50mm



28mm

From London and Upton

Caméra Digitale

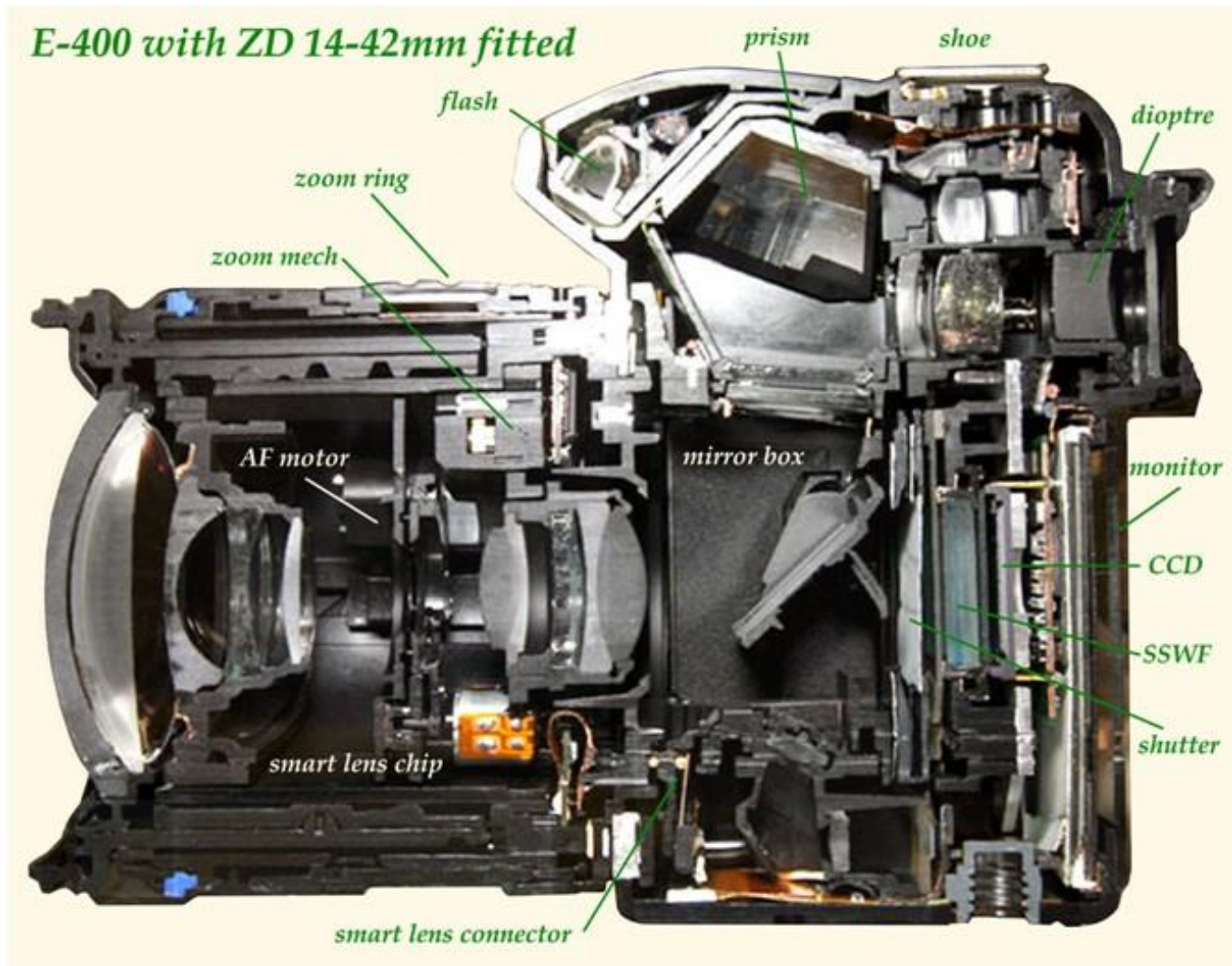


a b

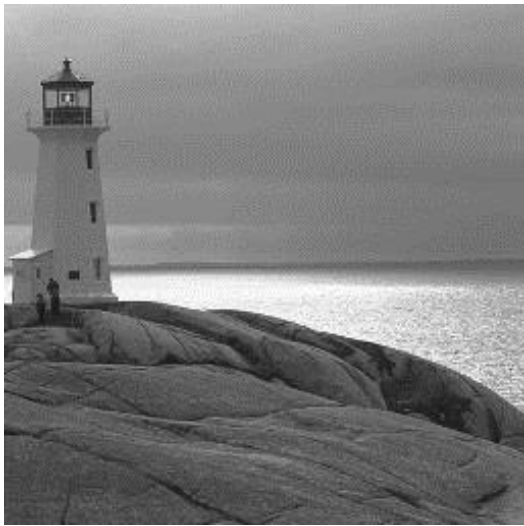
FIGURE 2.17 (a) Continuous image projected onto a sensor array. (b) Result of image sampling and quantization.

- Une caméra digitale remplace le film photographique par une matrice de détecteurs
 - Each cell in the array is light-sensitive diode that converts photons to electrons
 - Two common types
 - Charge Coupled Device (CCD)
 - Complementary metal oxide semiconductor (CMOS)
 - <http://electronics.howstuffworks.com/digital-camera.htm>

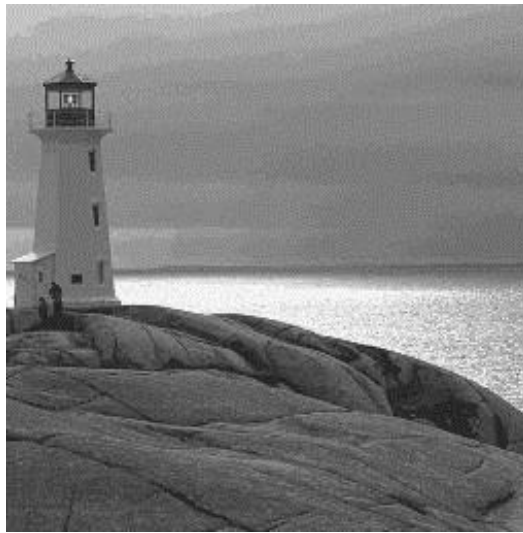
Single-lens reflex camera, across-section



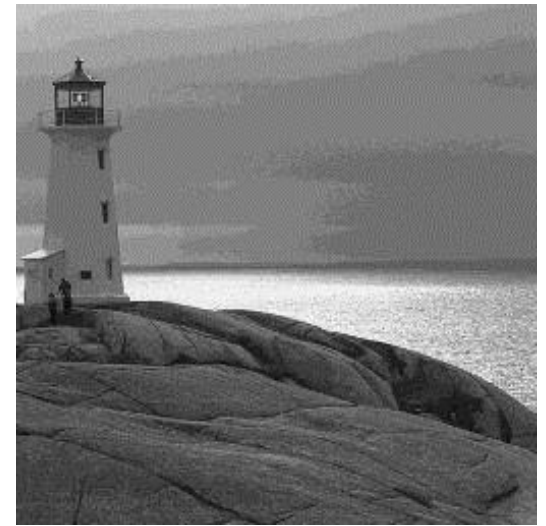
Example



8 bits image



4 bits image
Uniform quantization



4 bits image
Optimal quantization

Quantification de la Couleur



2 couleurs



16 couleurs



4 couleurs



256 couleurs

Echantillonnage d'image : exemple 1



Original 256×256



128×128

Echantillonnage d'image : exemple 2



Original 256×256

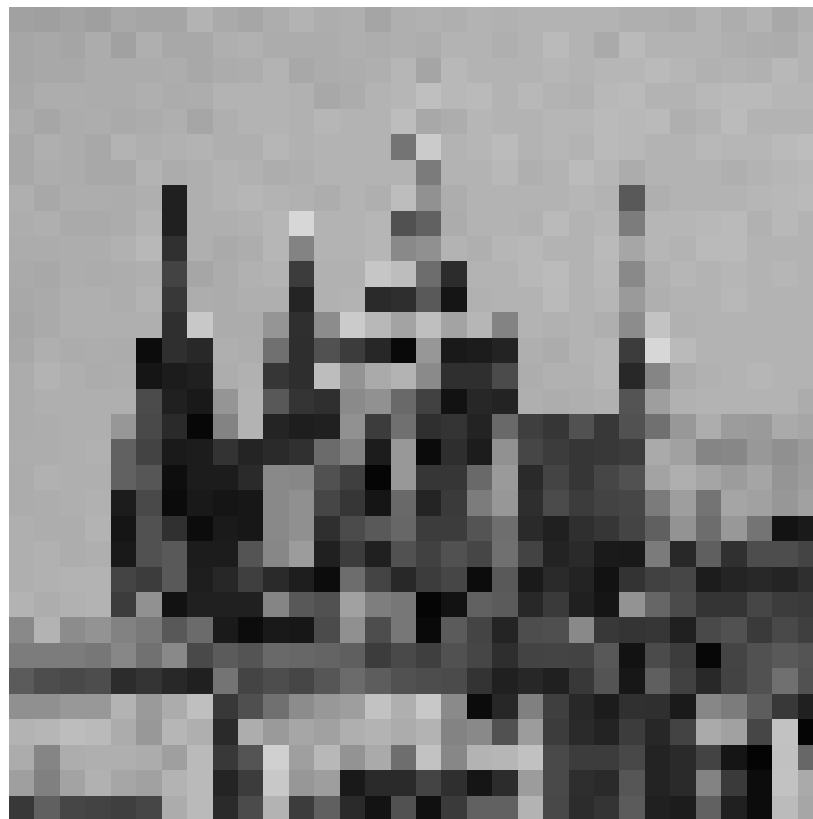


64×64

Echantillonnage d'image : exemple 3



Original 256×256



32×32

quantification d'une image : exemple 1



Original **256** gray levels



64 gray levels

quantification d'une image : exemple 2



Original 256 gray levels



16 gray levels

quantification d'une image : exemple 3



Original 256 gray levels



4 gray levels

quantification d'une image : exemple 4 (image binaire)

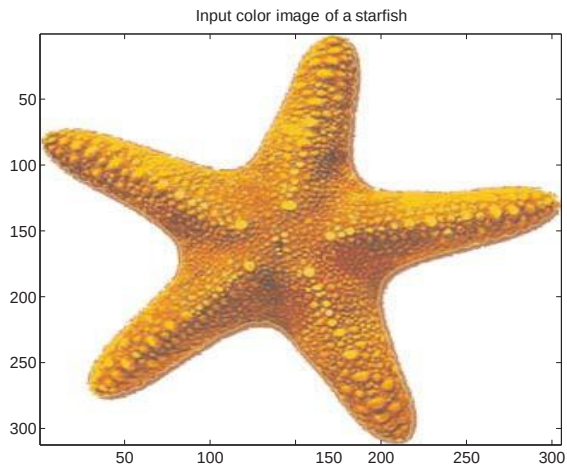


Original 256 gray levels

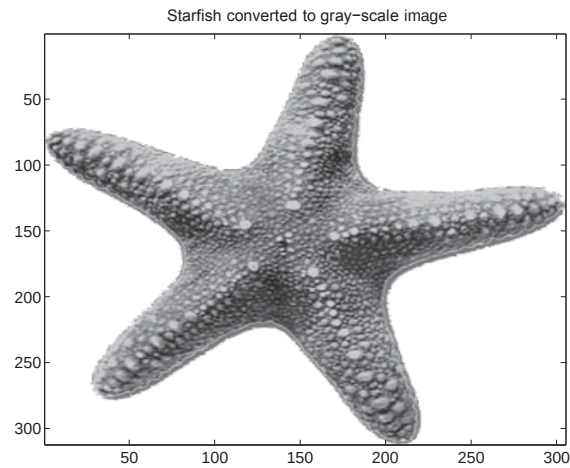


2 gray levels

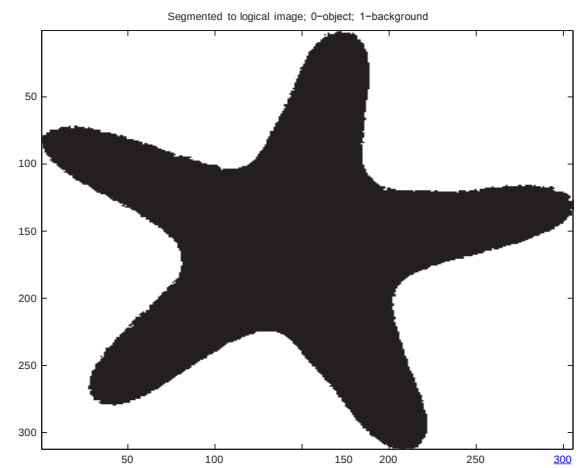
exemple d'image : étoile



couleur

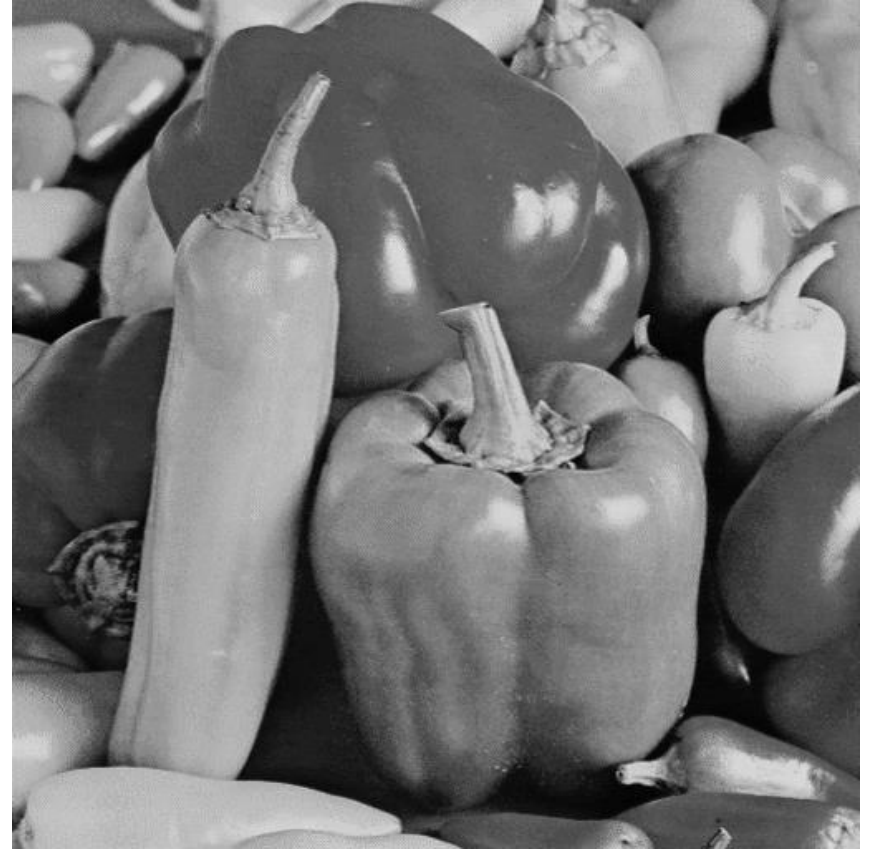
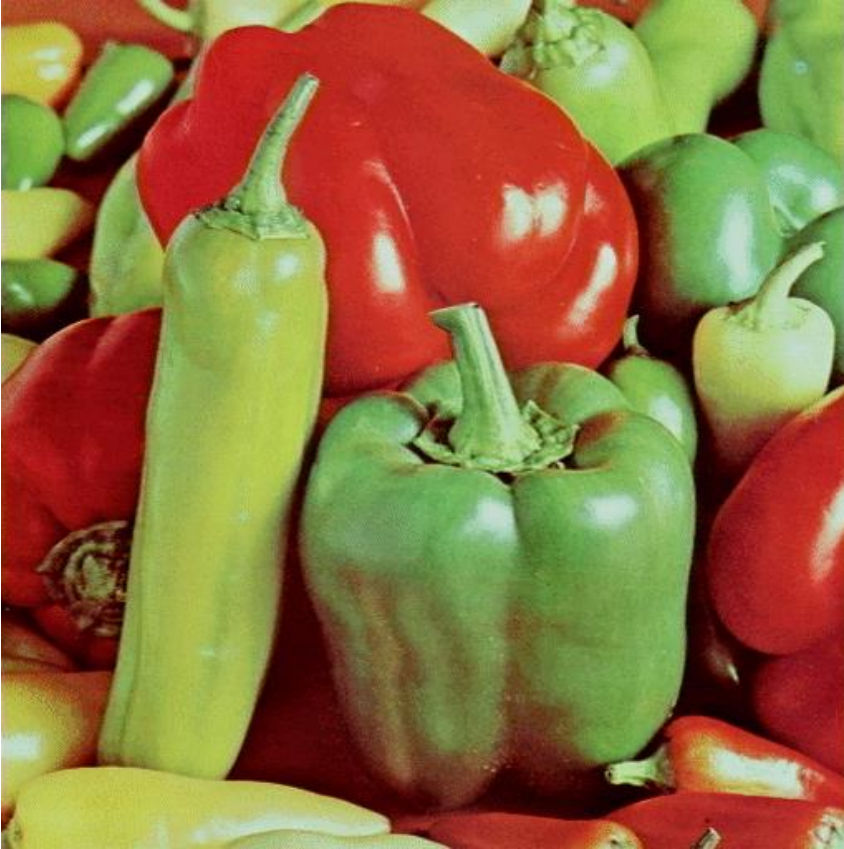


Grayscale
ou
niveaux
de gris

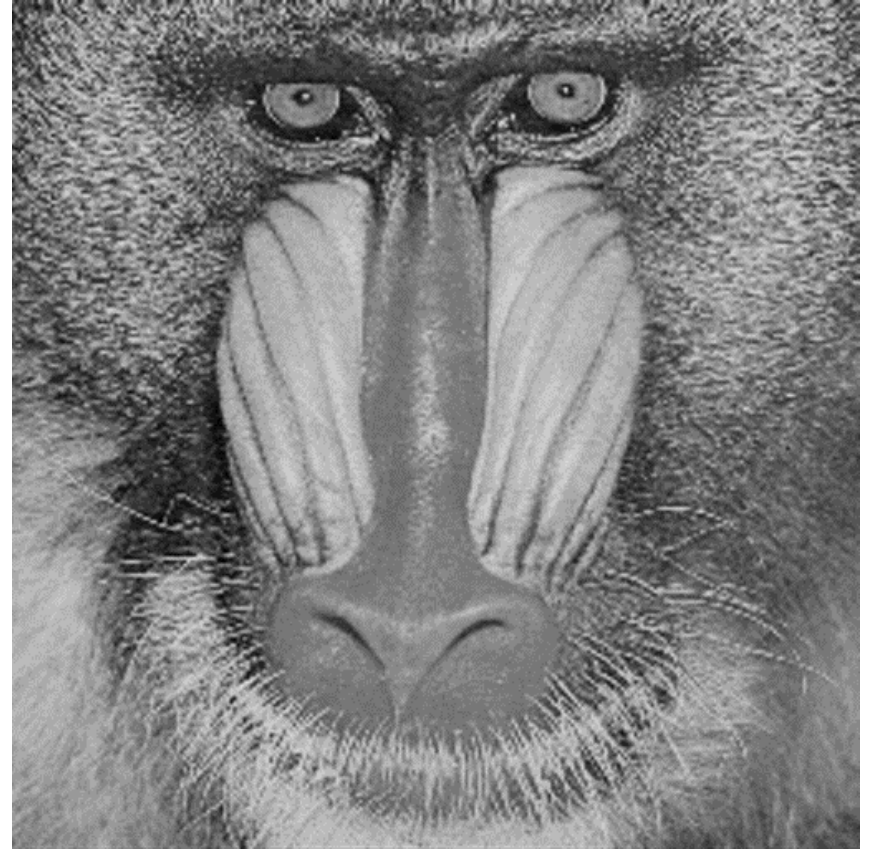
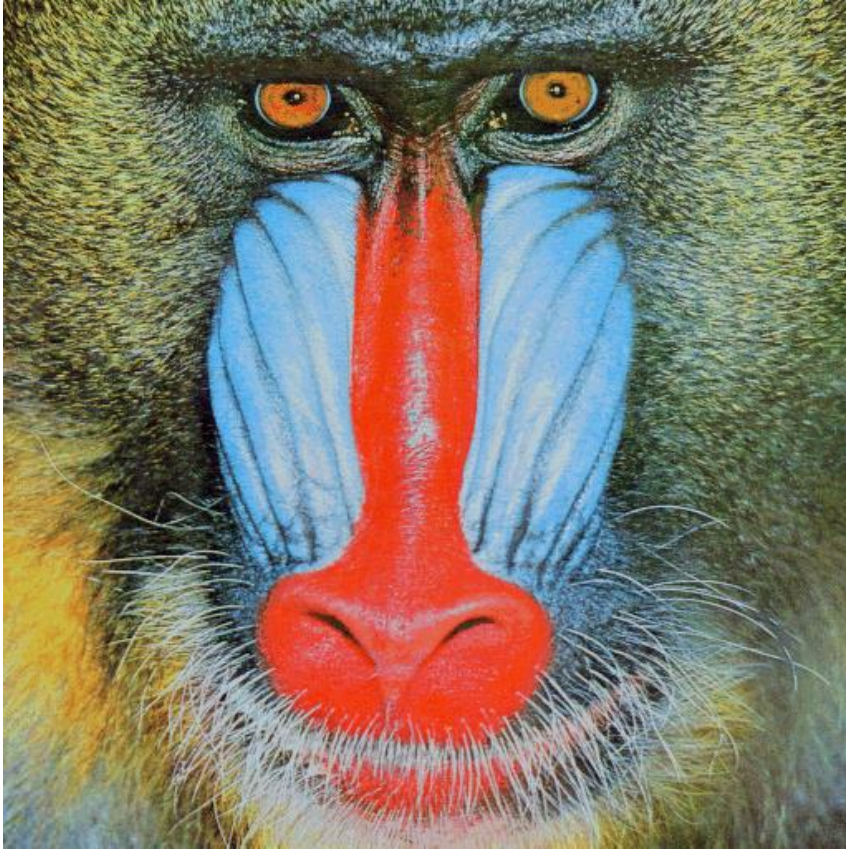


binaire

Exemple d'images couleur et à niveaux de gris -1

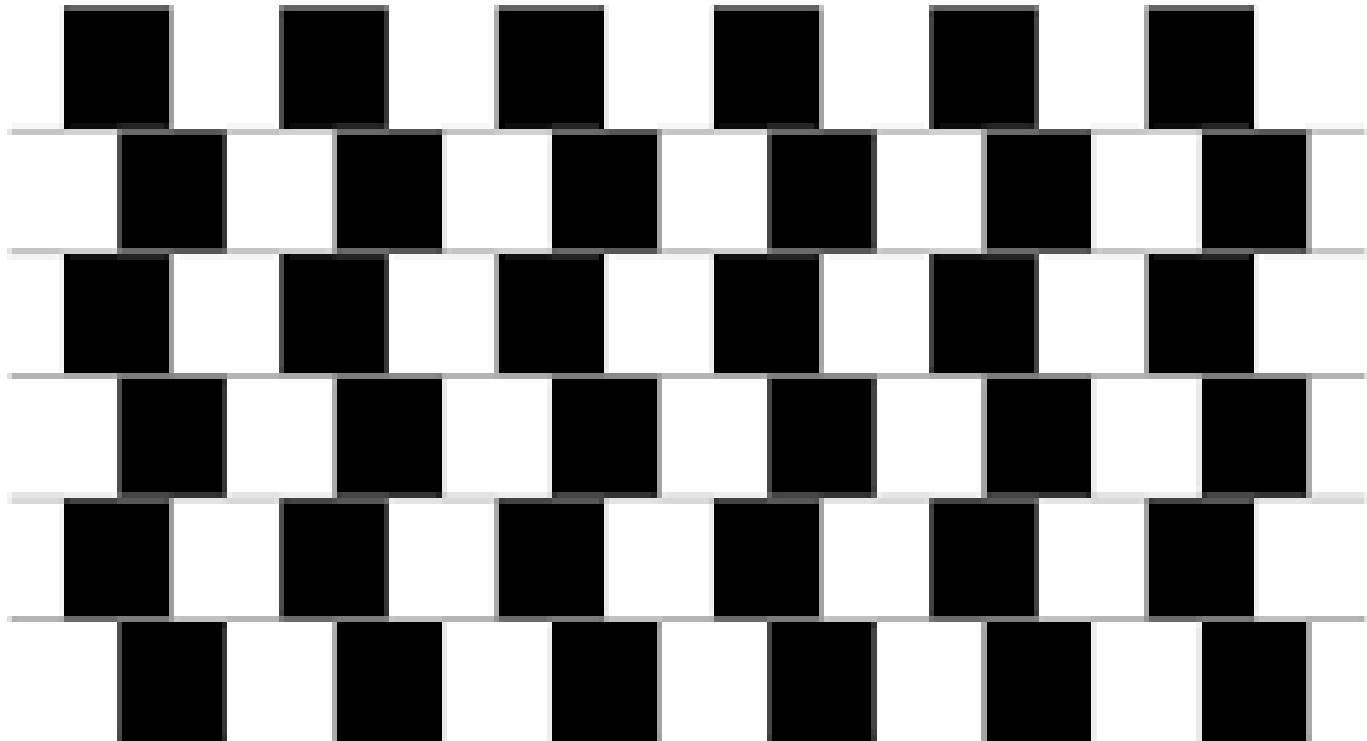


Exemple d'images couleur et à niveaux de gris -2



Fin :

illusion optique



Fin :

illusion optique

