

# **Světlo a barvy v přírodě**



**Ara arakanga** (*Ara macao*)

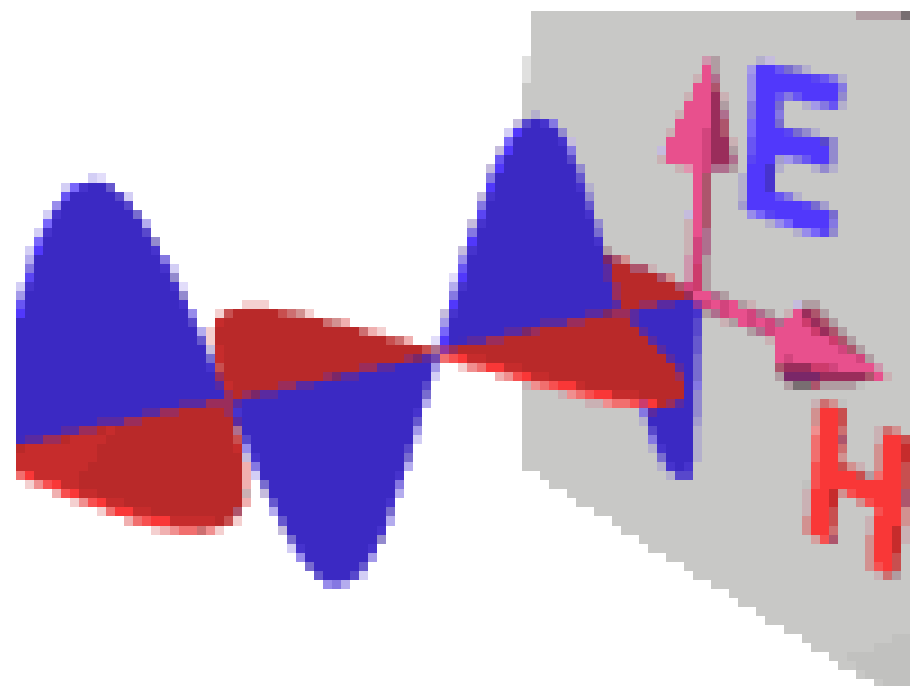
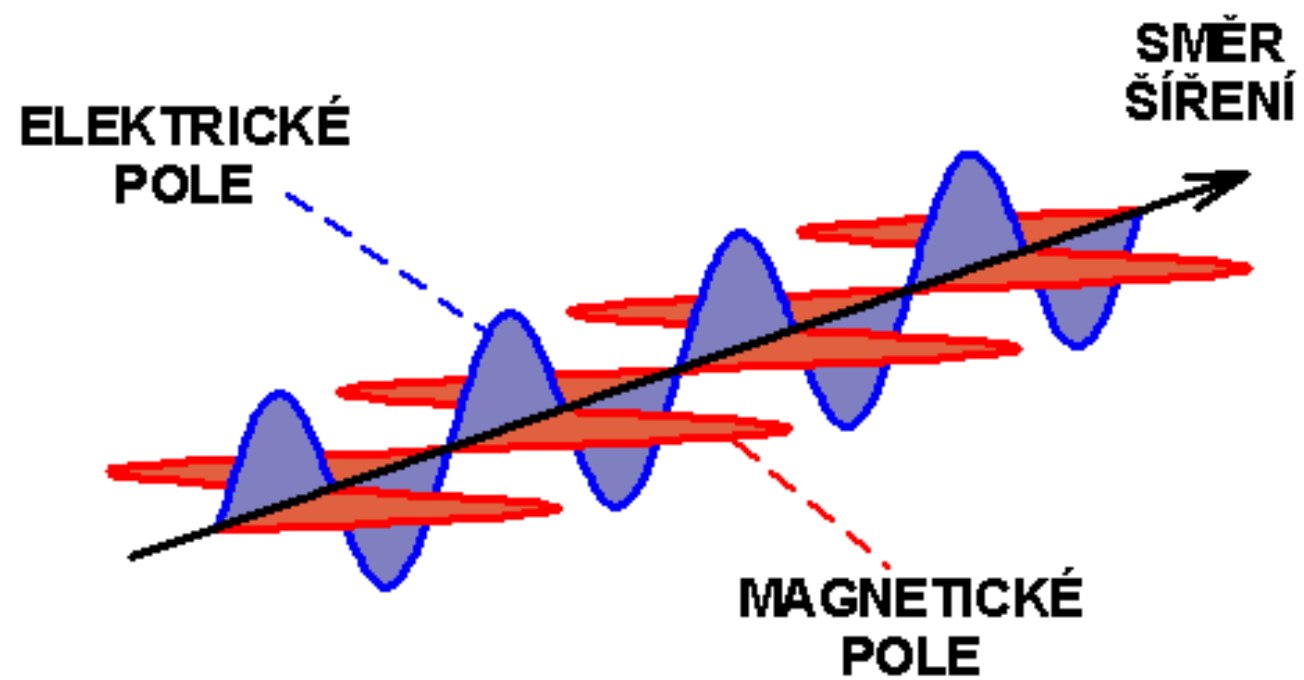




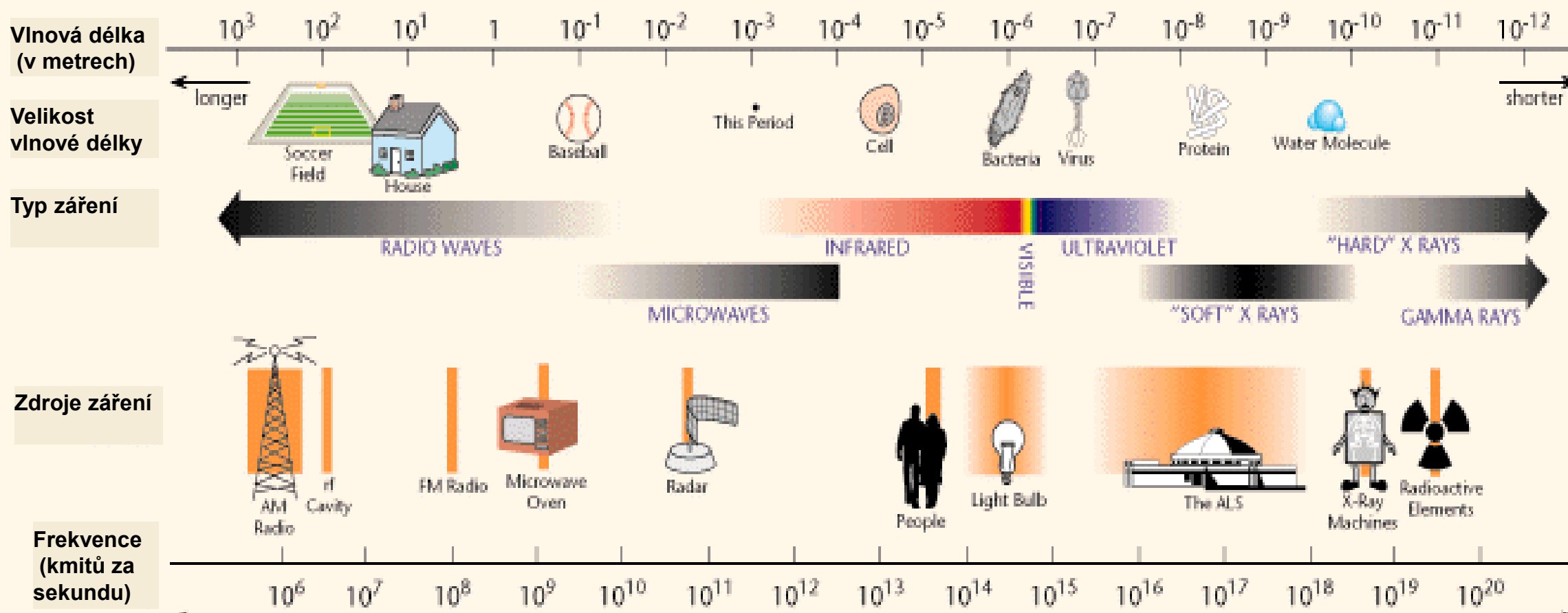
*Morpho menelaus*

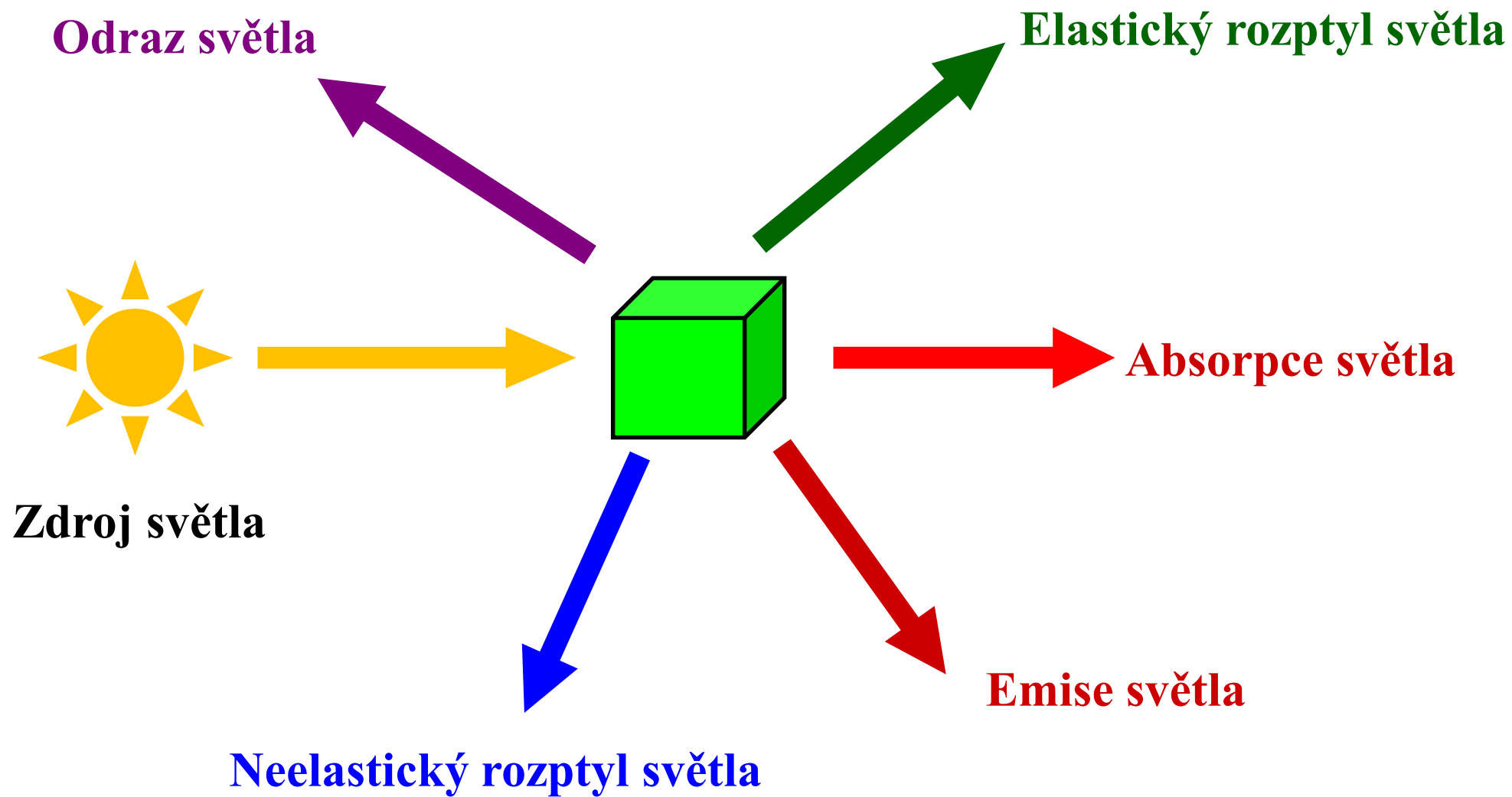


**Zlatohlávek zlatý** (*Cetonia aurata*)

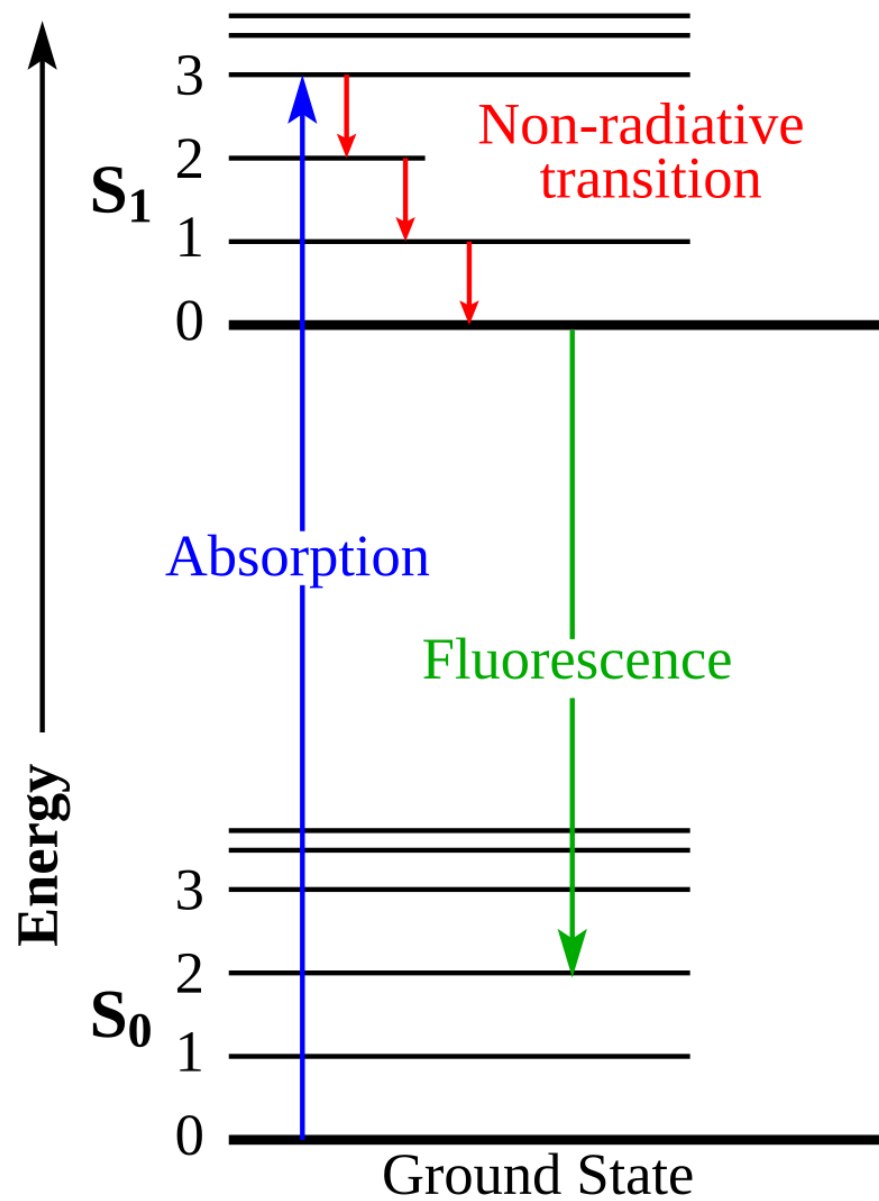


# THE ELECTROMAGNETIC SPECTRUM





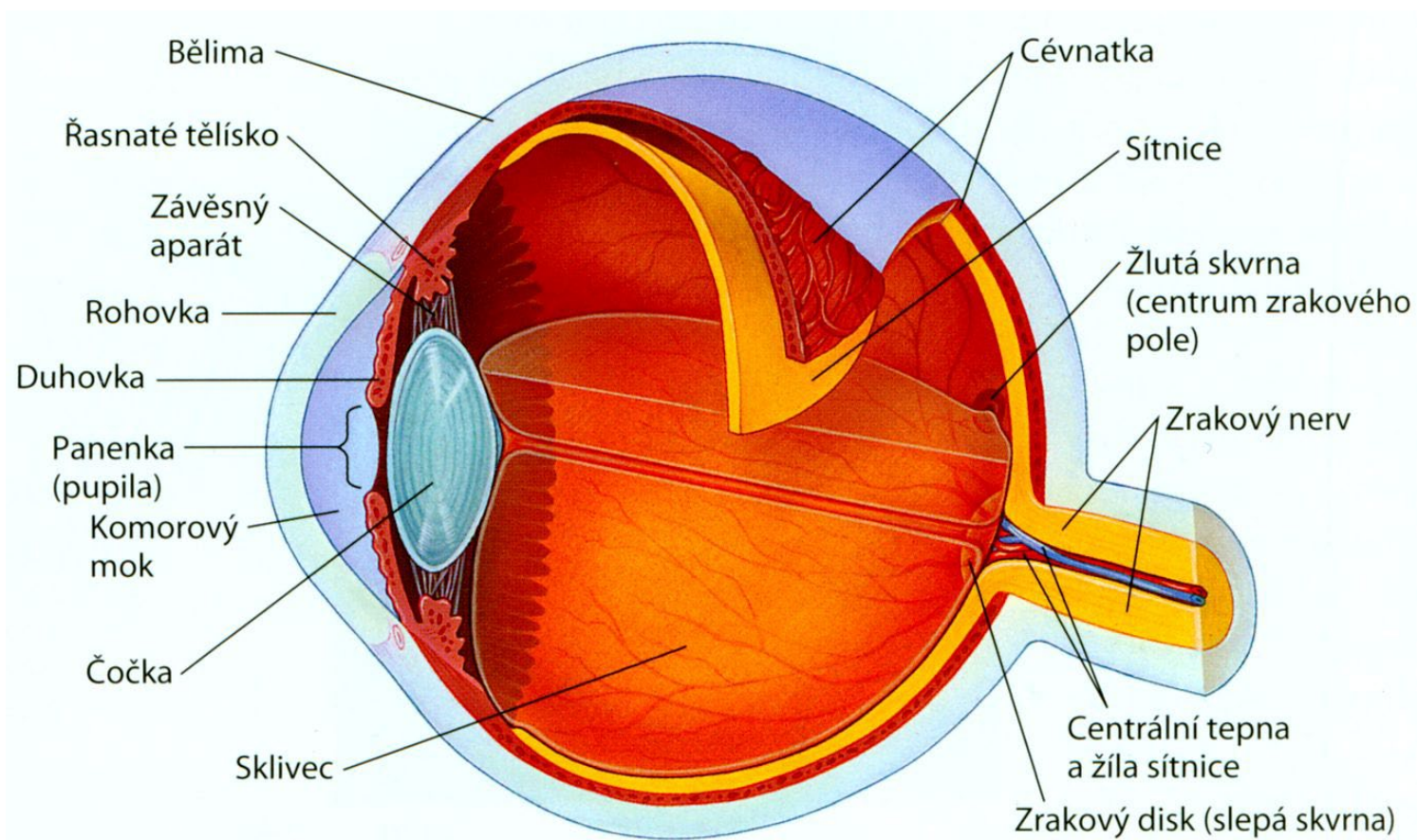
# Jablonského diagram



## **Fyzikální jevy odpovídající za barvy v přírodě**

- Absorpce
- Emise
- Rozptyl/Odraz
- Interference

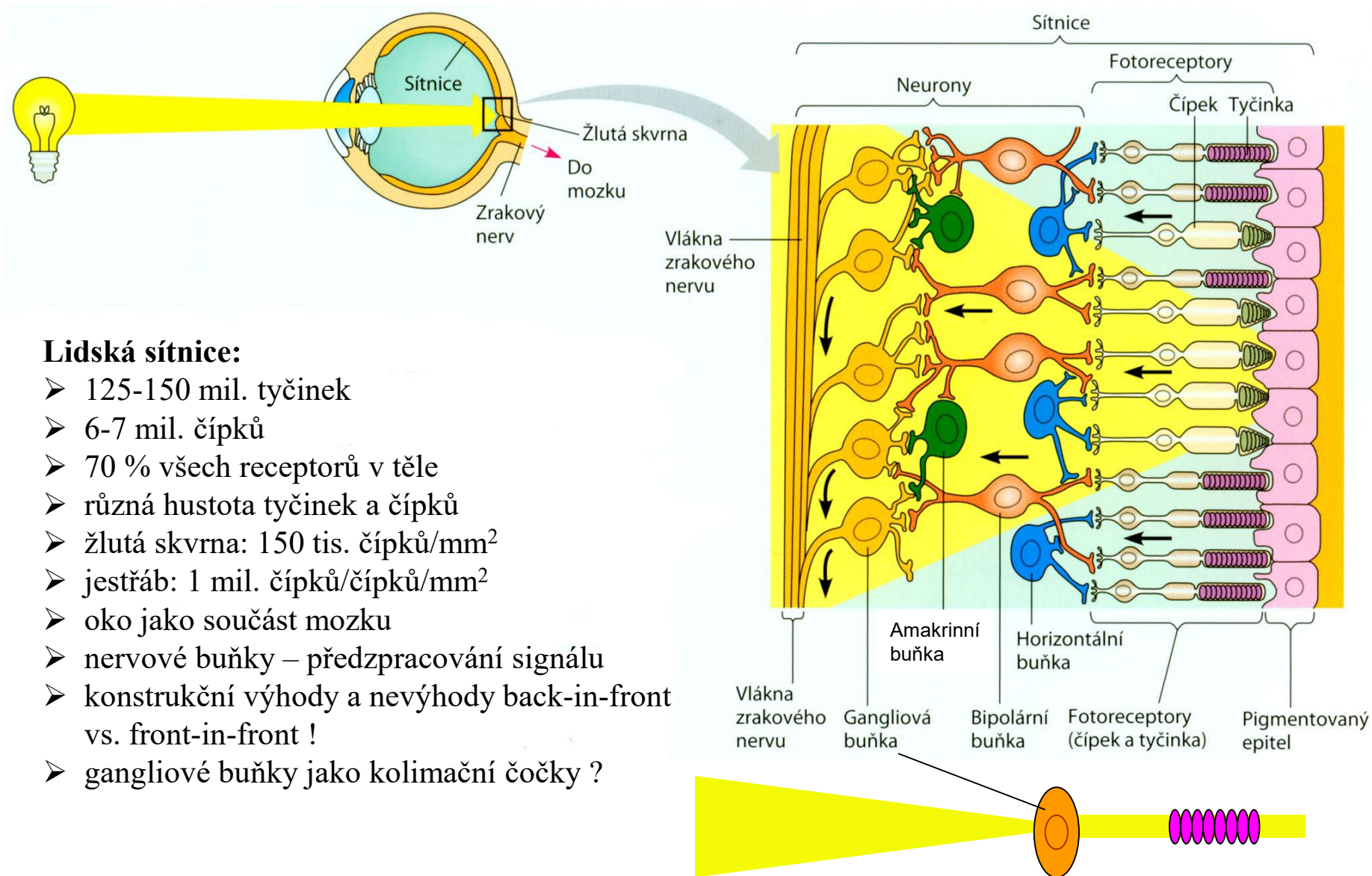
# Struktura lidského oka



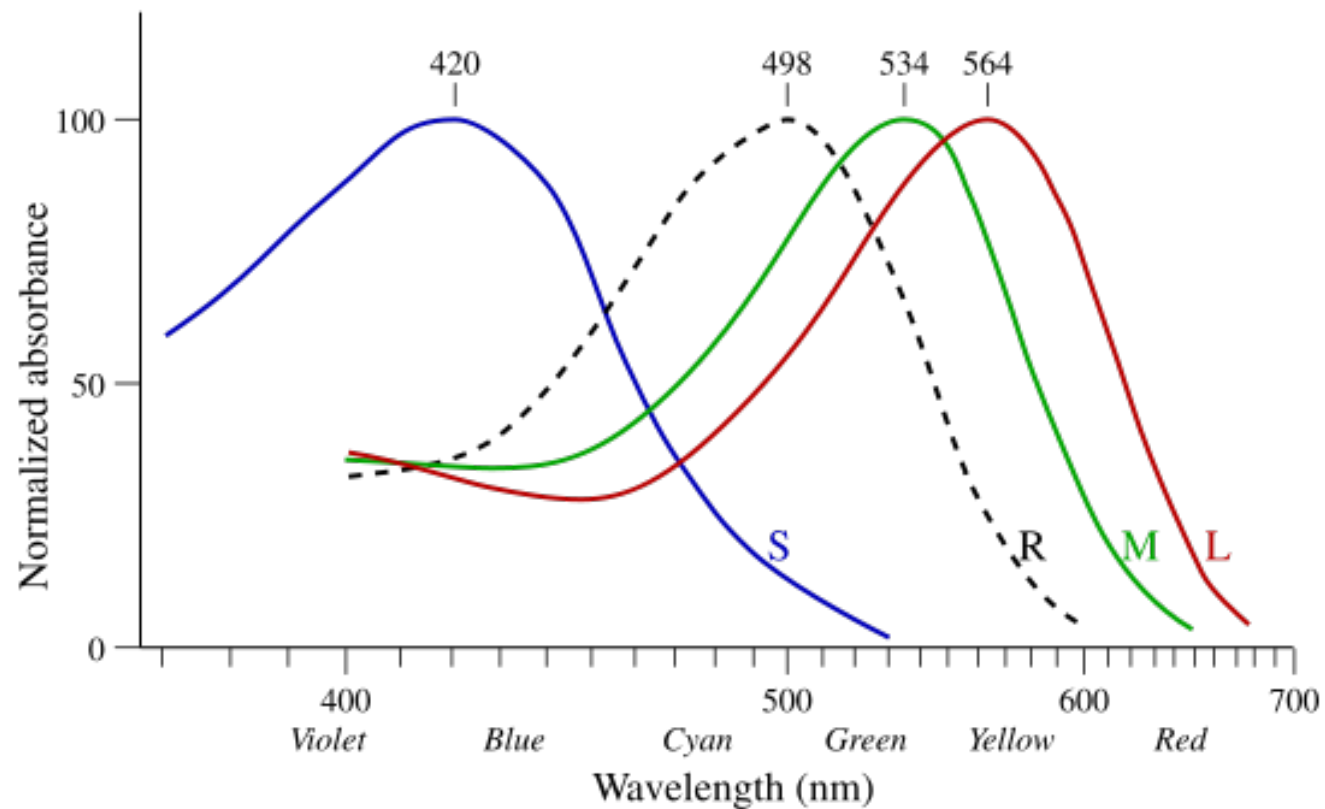
## Indexy lomu:

- voda 1.33
- rohovka 1.37
- komorový mok 1.33
- čočka 1.40 (střed) – 1.38 (okraje)

# Struktura sítnice obratlovců: konstrukce „back-in-front“



# Barevné vidění a zrakové pigmenty



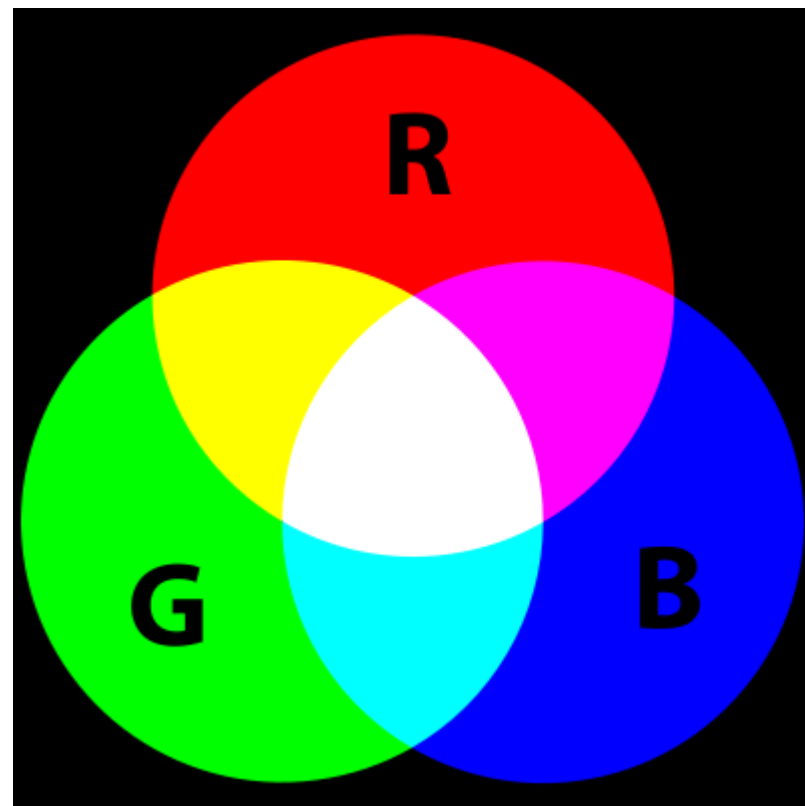
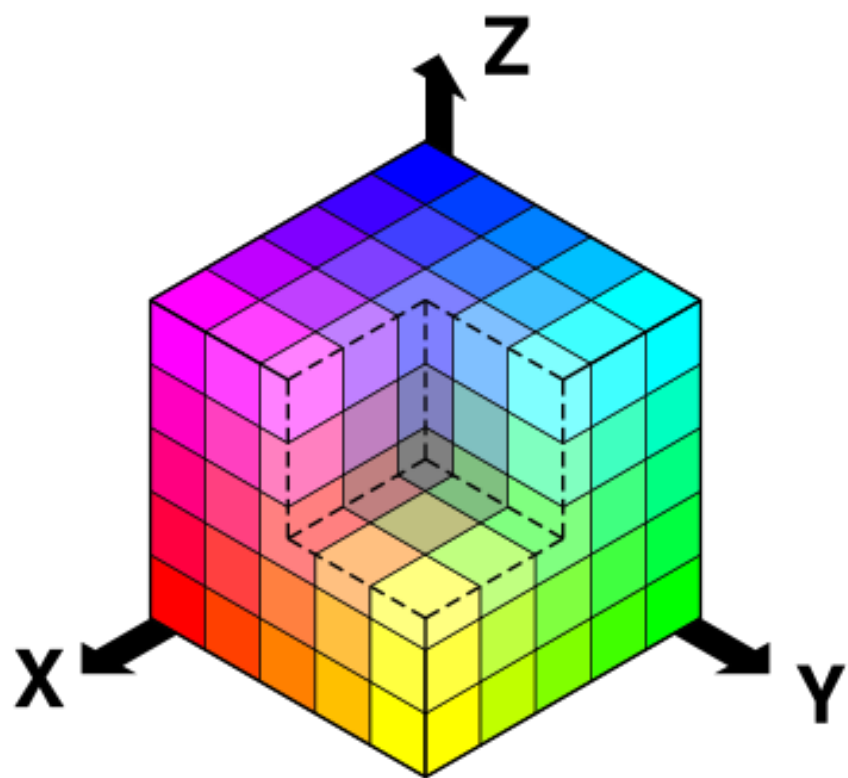
R – rodopsin (v tyčinkách)

## Fotopsiny (iodopsiny):

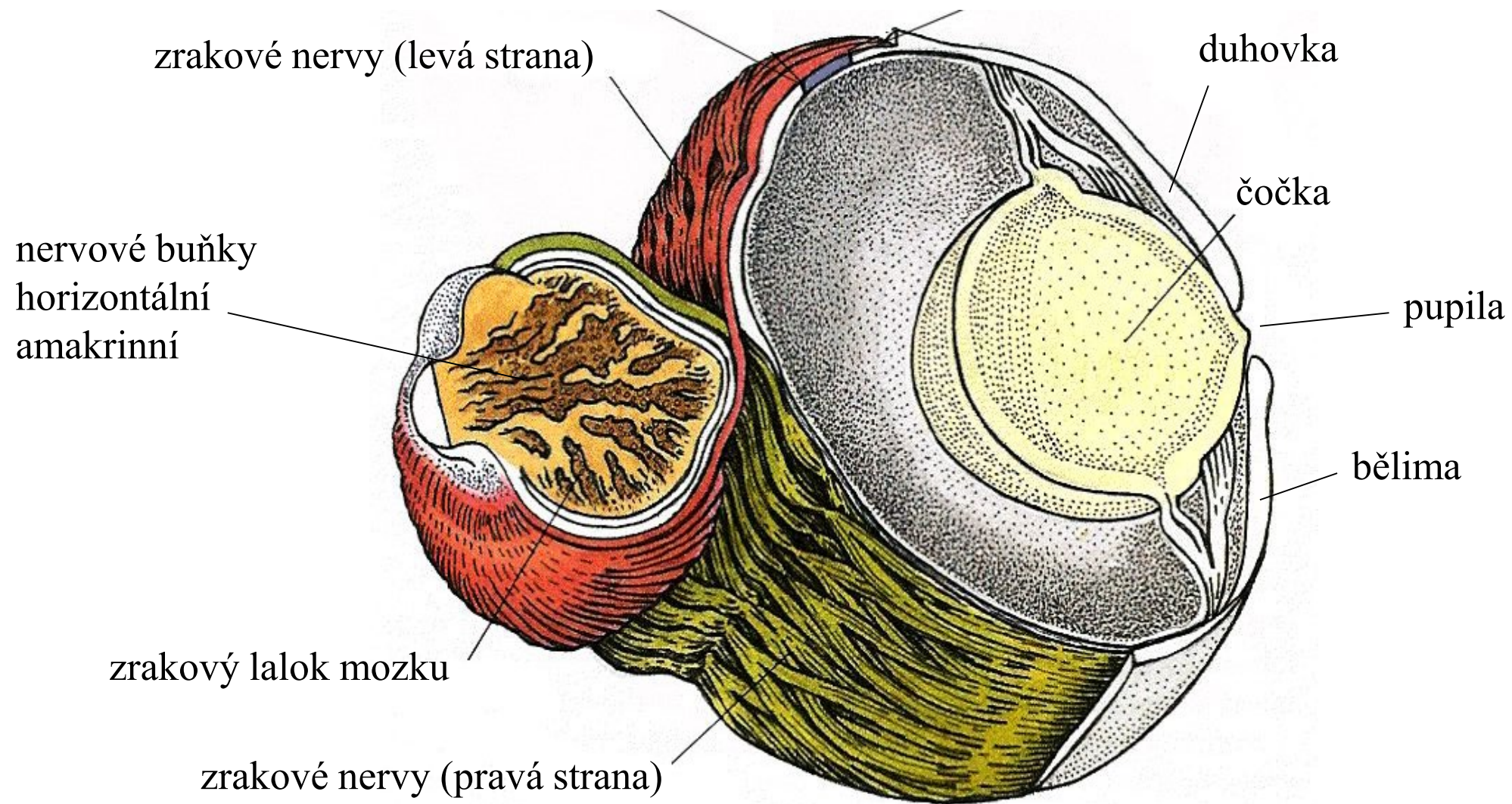
S – modrá oblast (cyanolabe, tritan)

M – zelená oblast (chlorolabe, deutan)

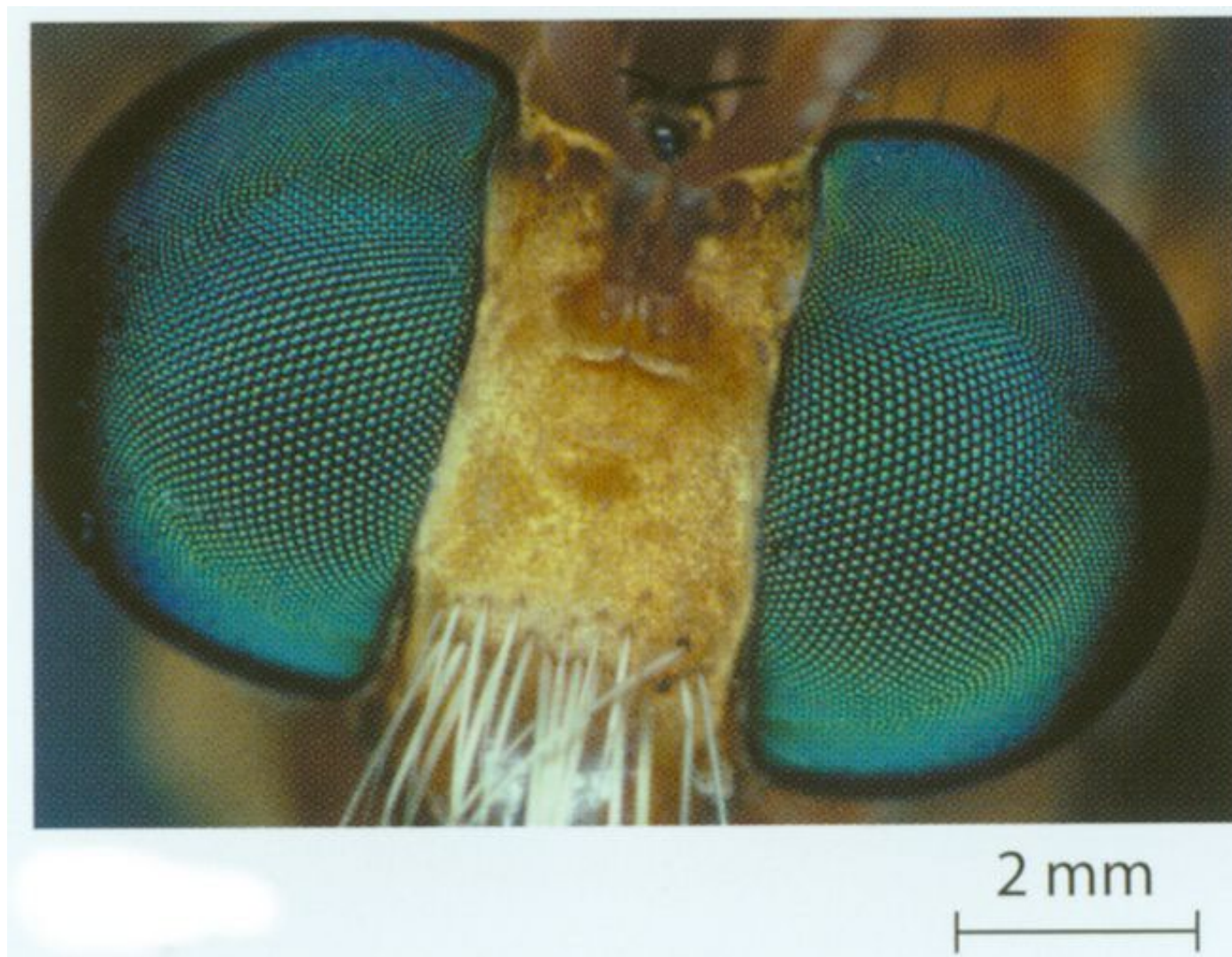
L – červená oblast (erythrolabe, protan)





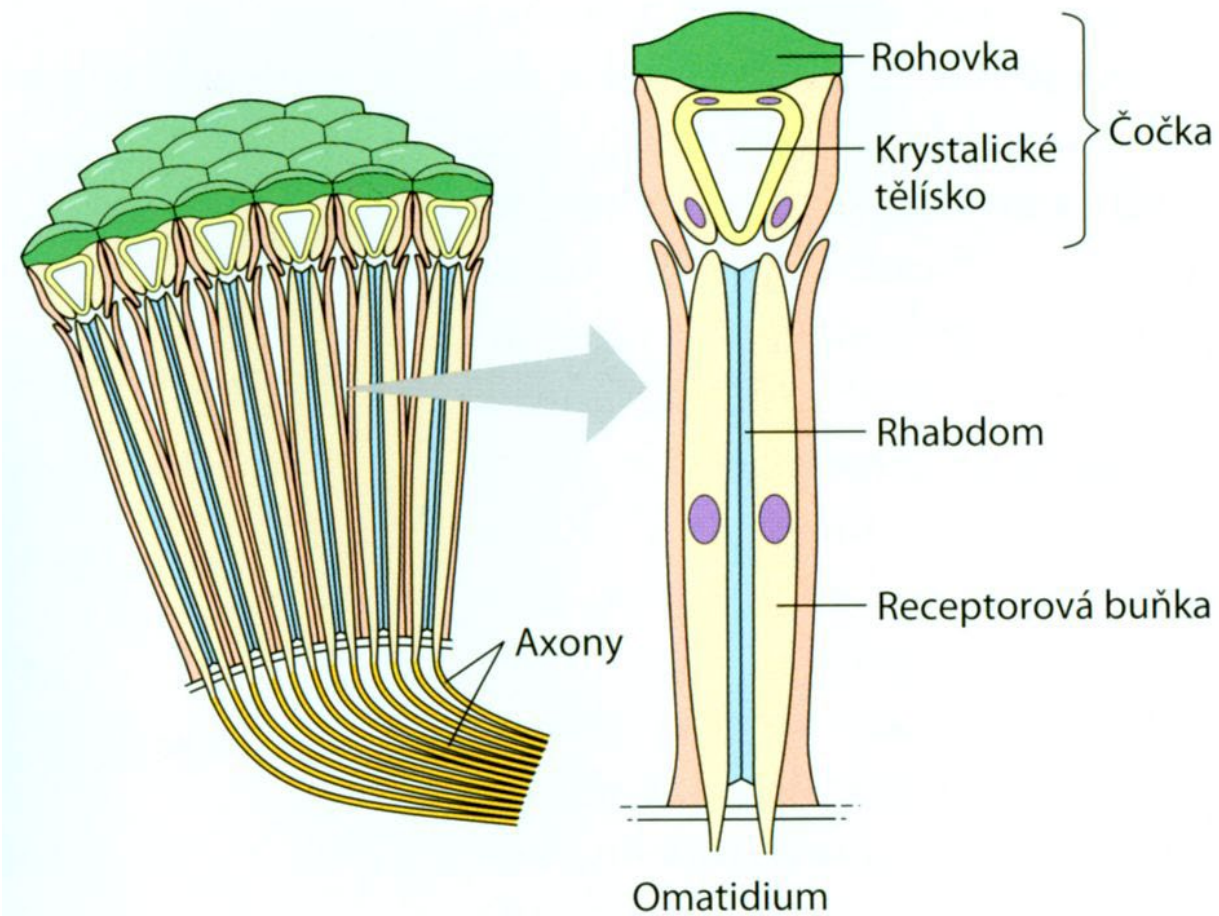


## Jsou i jiné oči ...



Facetované oči mouchy – mozaika z tisíců samostatných fotodetektorů (ommatidia)

# Struktura omatidia



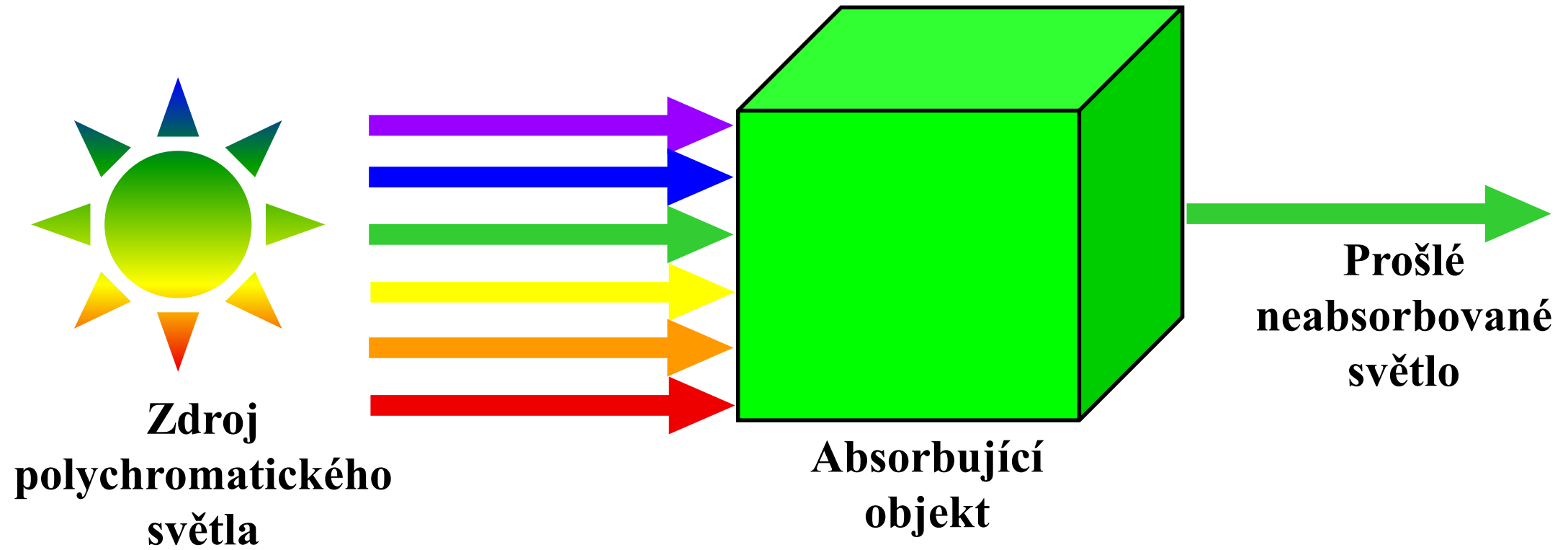
- limitované prostorové rozlišení
- vysoké časové rozlišení (až 330 Hz)
- barevné vidění (i UV)
- citlivost k polarizaci světla

## **Fyzikální jevy odpovídající za barvy v přírodě**

- Absorpce
- Emise
- Rozptyl/Odraz
- Interference

# Absorpce světla

# Absorpce světla



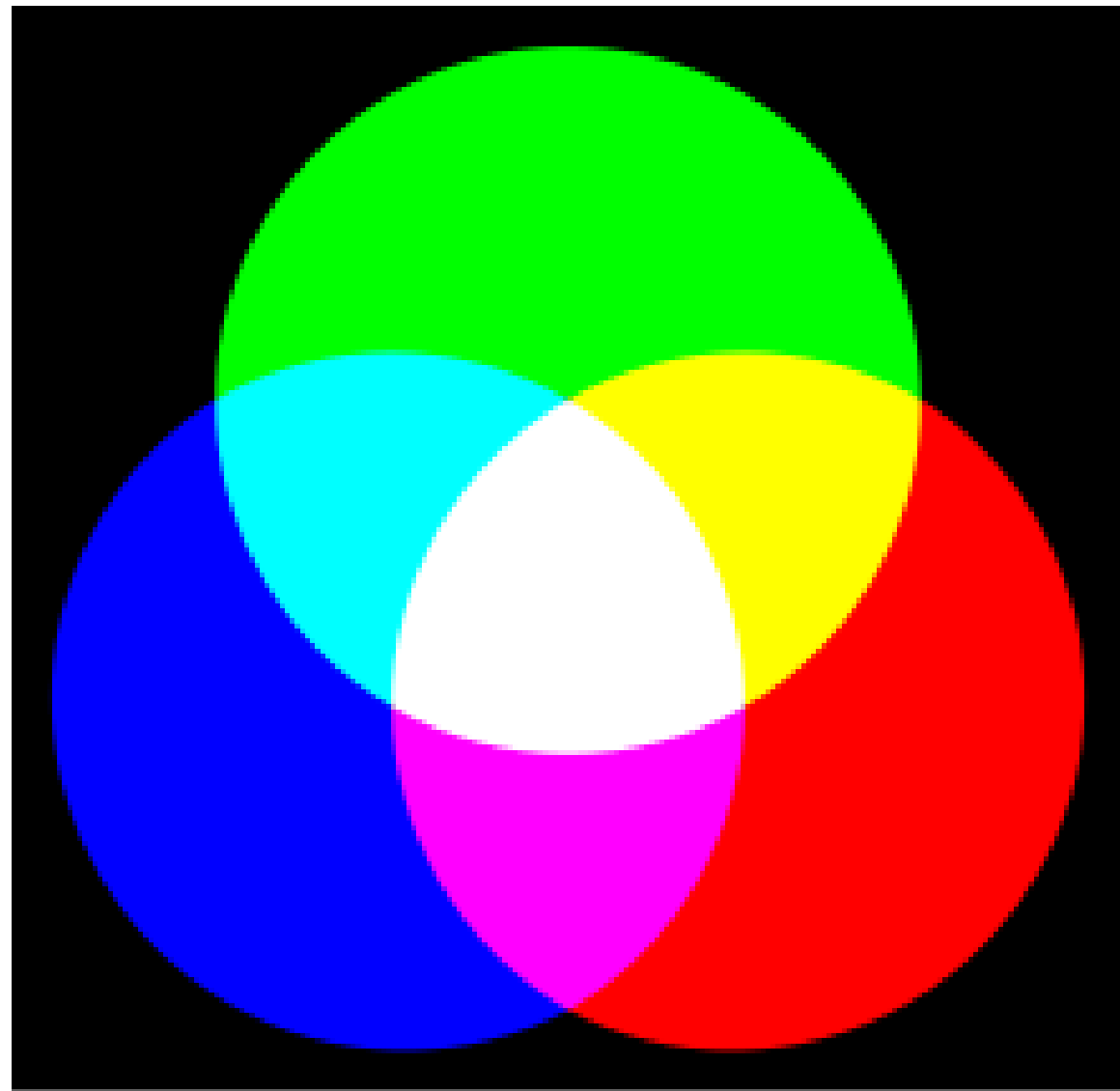
# Komplementární barvy



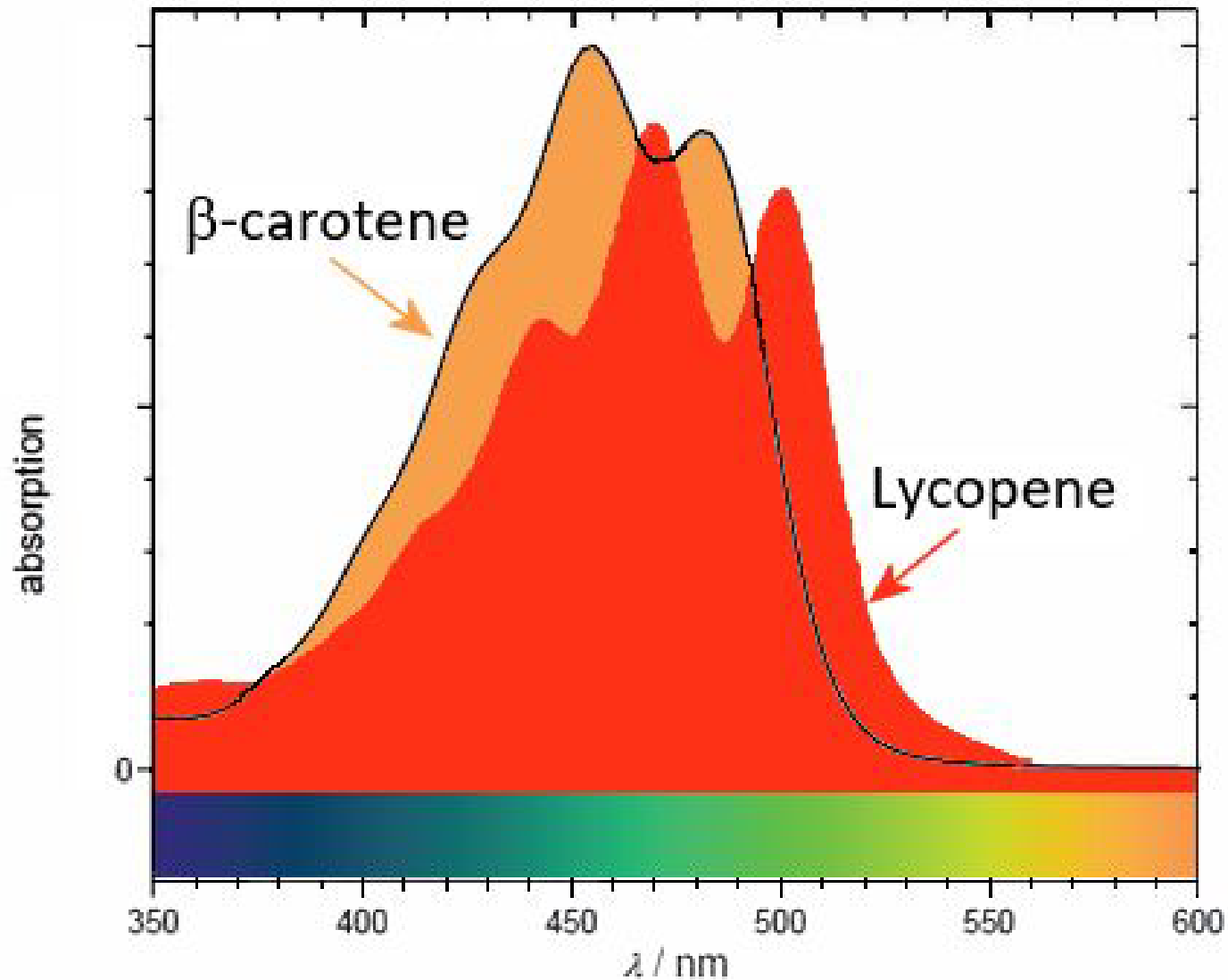
Subtraktivní míchání barev



Aditivní míchání barev



## Pigmenty



- Chlorofyly
- Karotenoidy
- Psitakofulviny
- Melaniny
- ....



## Karotenoidy



Plameňák kubánský (*Phoenicopterus ruber ruber*)

## Psitakofulviny



Ara arakanga (*Ara macao*)

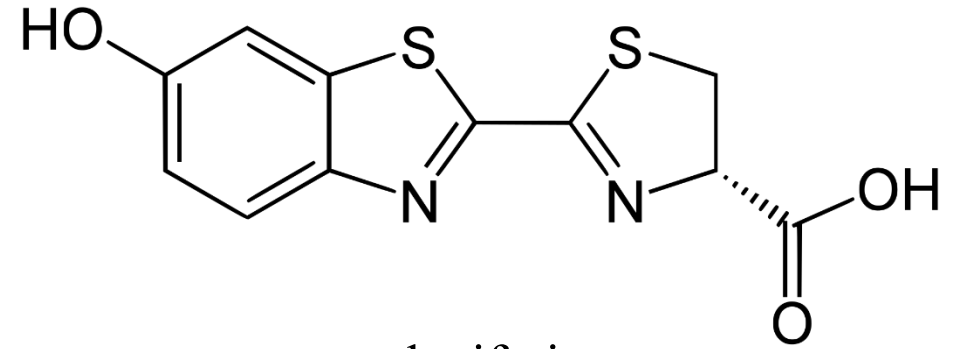
# **Emise světla**

# **Fluorescence**

Světluška větší (*Lampyris noctiluca*)



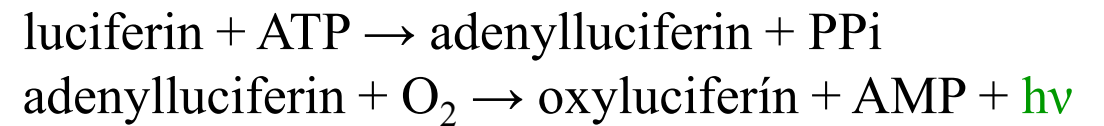
## Bioluminescence / chemiluminescence



luciferin

+

enzym luciferáza



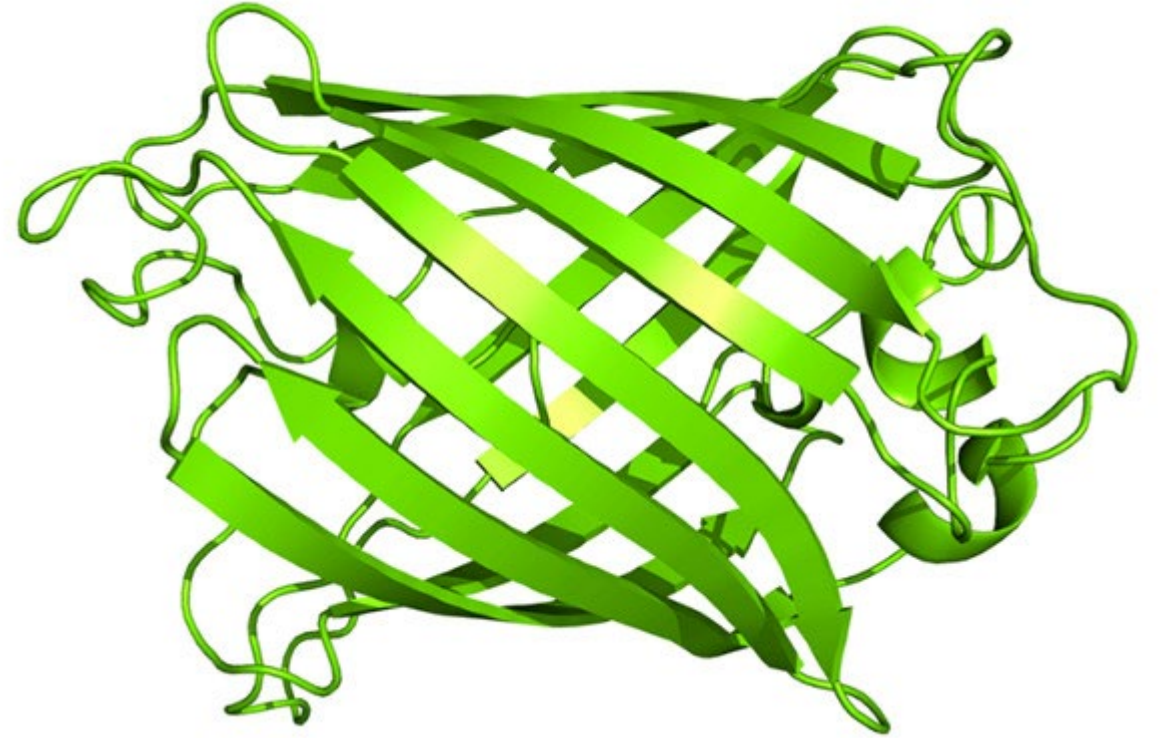
96% účinnost

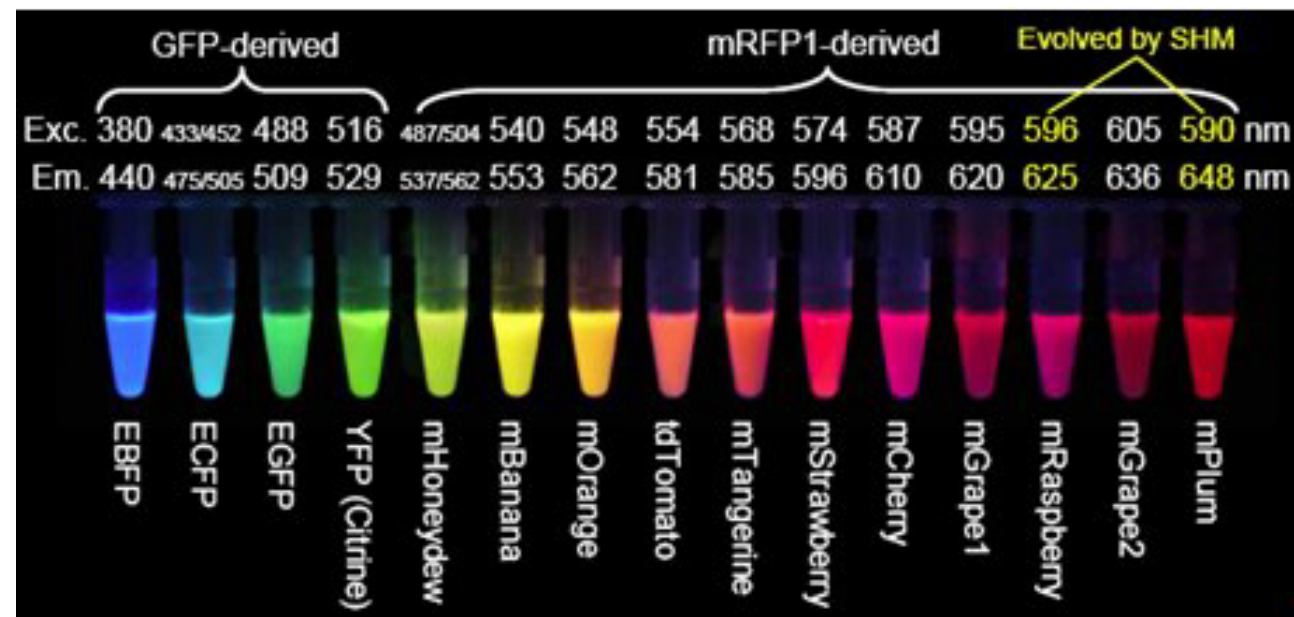
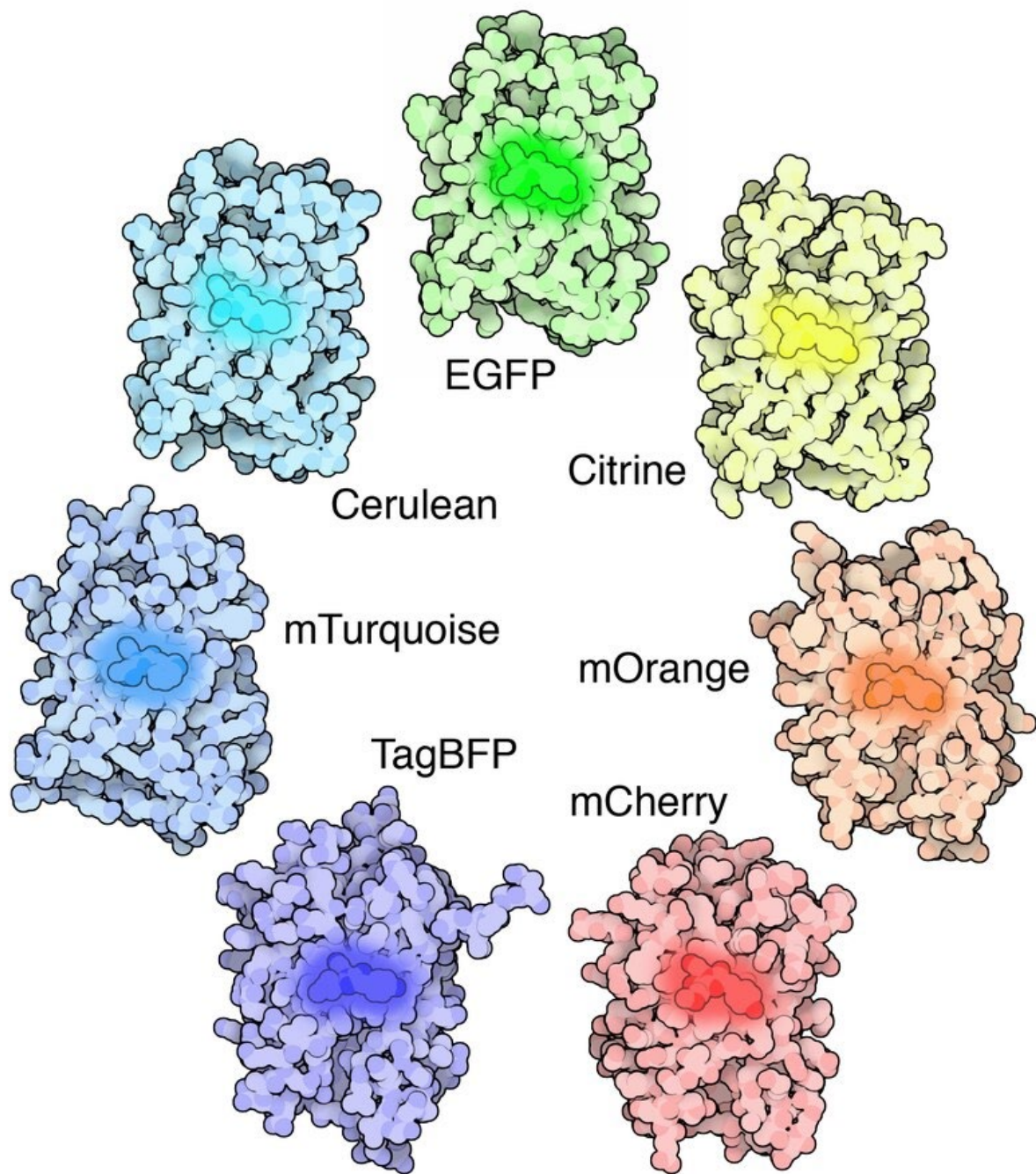


# GFP- zelený fluorescenční protein



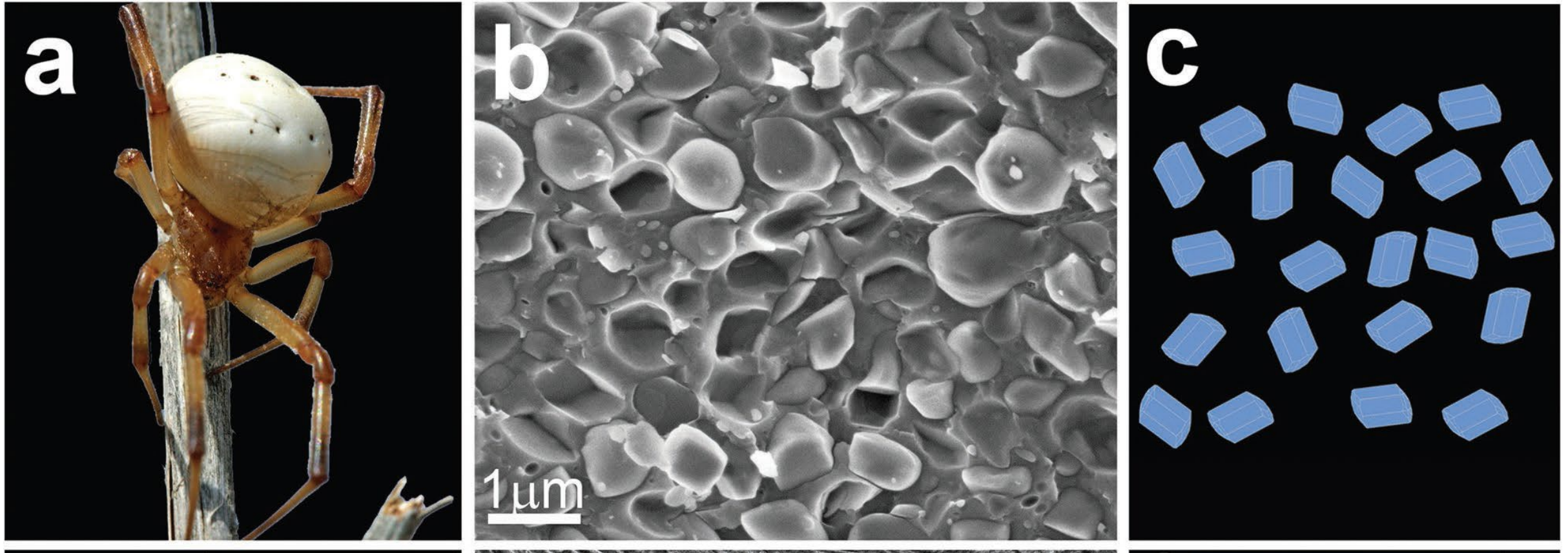
*Aequorea victoria*





# Rozptyl/odraz světla

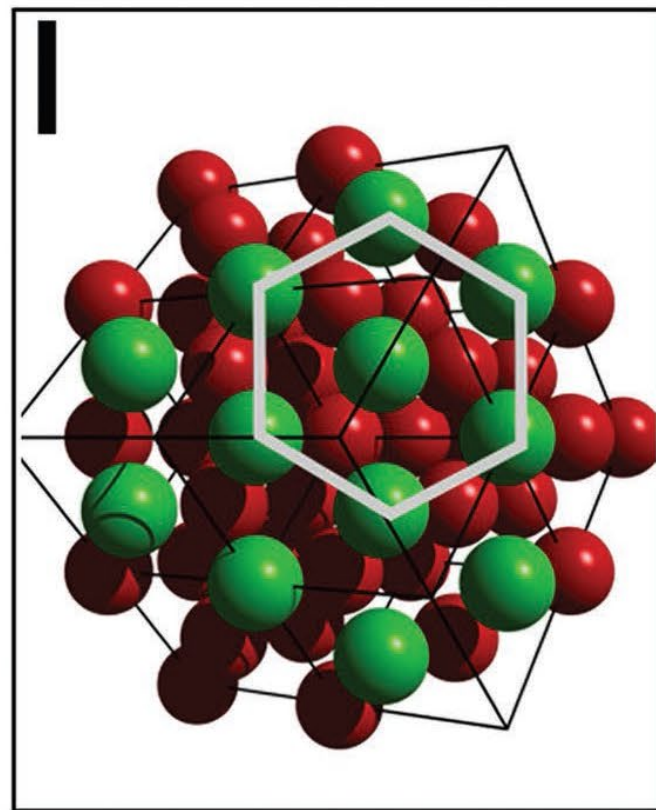
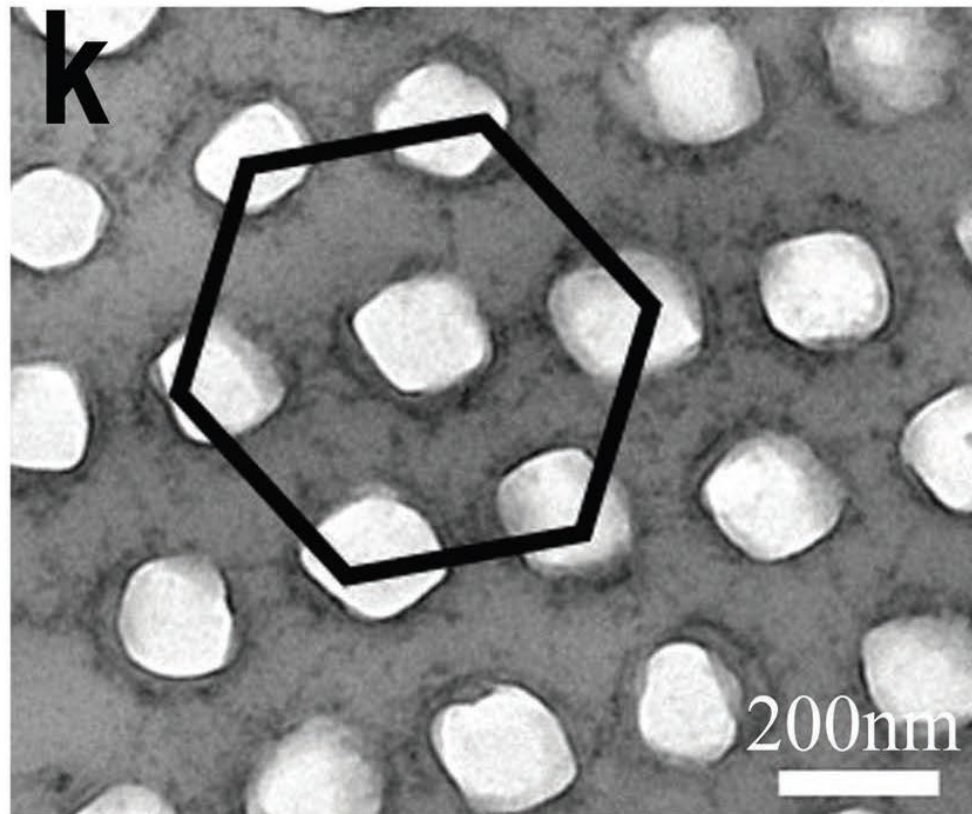
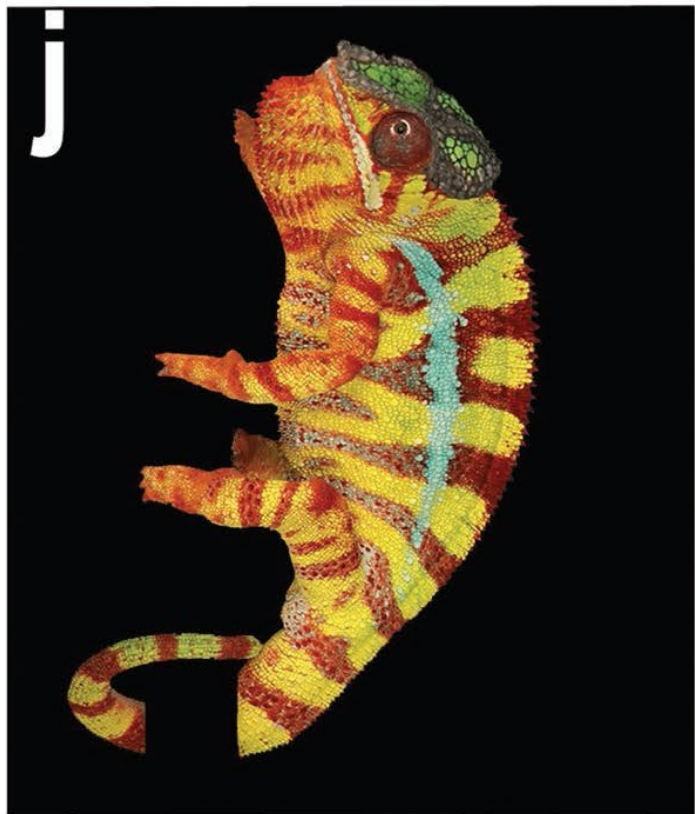
## White widow spider (*Latrodectus pallidus*)



Gur, D.; Palmer, B. A.; Weiner, S.; Addadi, L., Light manipulation by guanine crystals in organisms: Biogenic scatterers, mirrors, multilayer reflectors and photonic crystals. *Advanced Functional Materials* **2017**, 27 (6), 1603514.

**Chameleon pardálí** (*Furcifer pardalis*)





# **Interference světla**

## **Strukturní barvy**

$$2(n_h d_{cryst} + n_l d_{cyt}) = m\lambda$$

$$n_h = 1.83$$

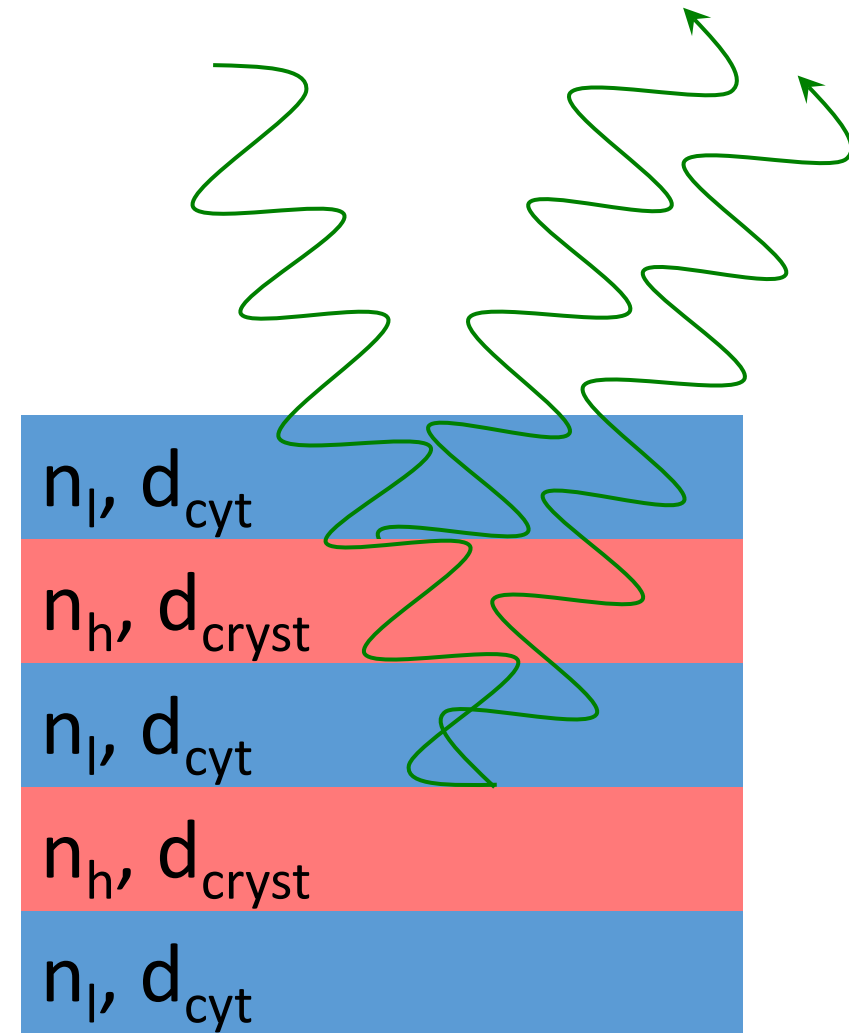
$$n_l = 1.33$$

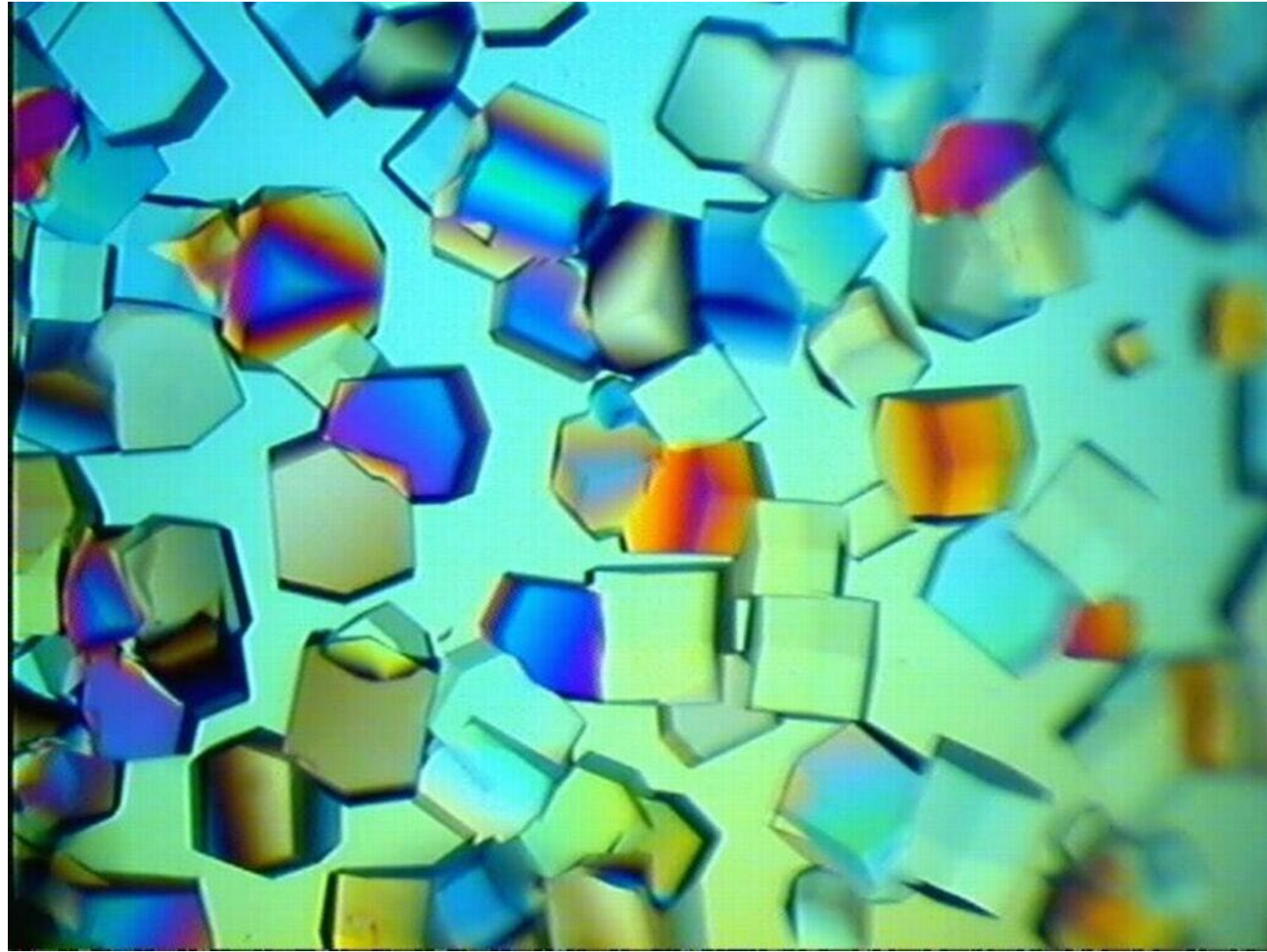
$$d_{cryst} = 74 \text{ nm}$$

$$d_{cyt} = 86 \text{ nm}$$

$$\lambda \sim 500 \text{ nm}$$

$$|R|^2 = \left| \frac{1 - \left(\frac{n_h}{n_l}\right)^{2N}}{1 + \left(\frac{n_h}{n_l}\right)^{2N}} \right|^2$$

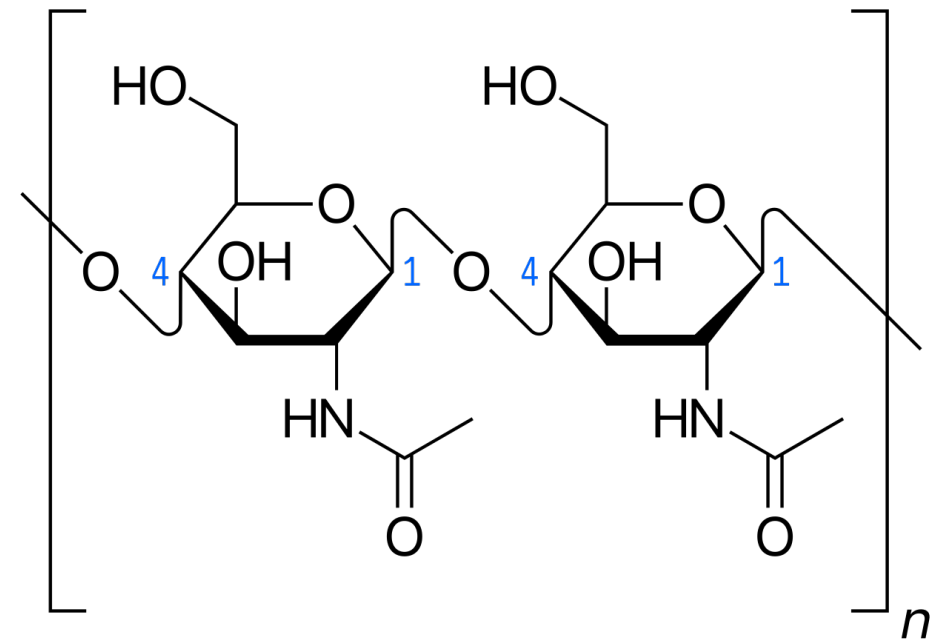




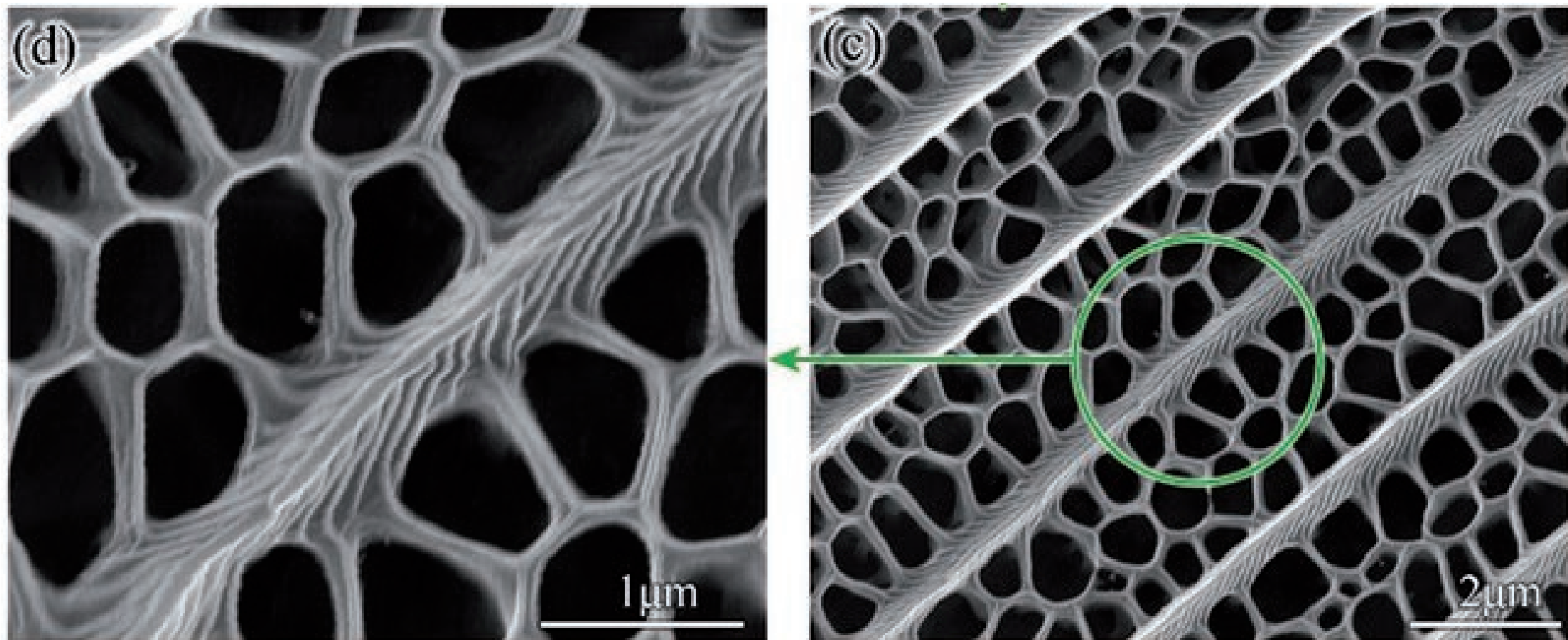
*Morpho menelaus*



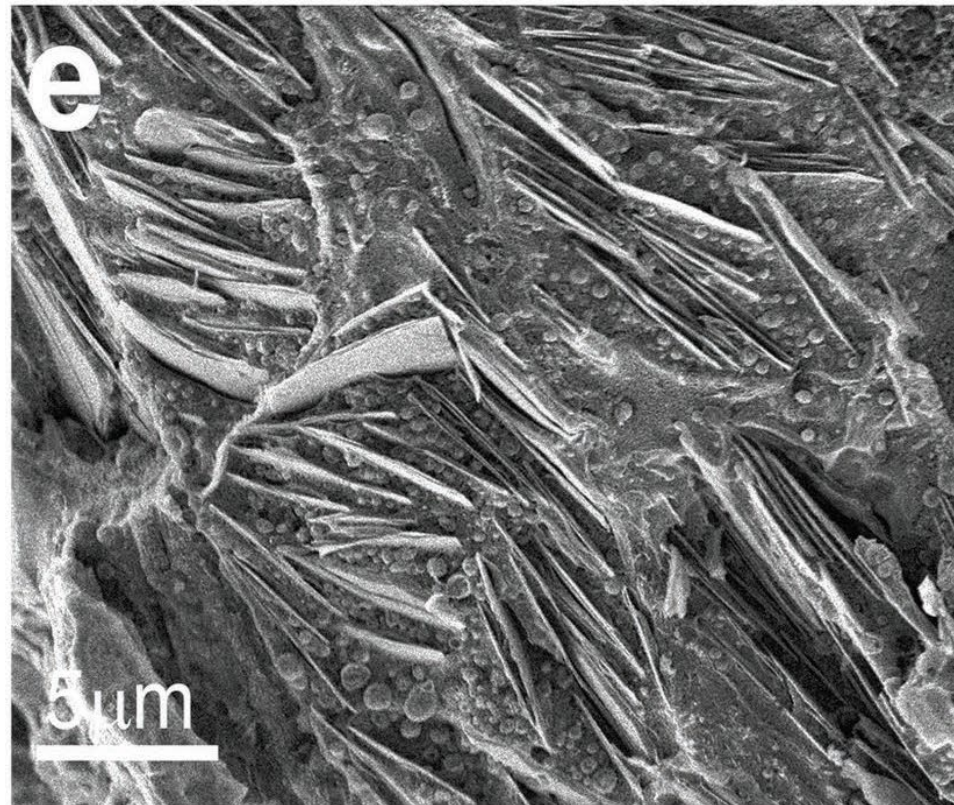
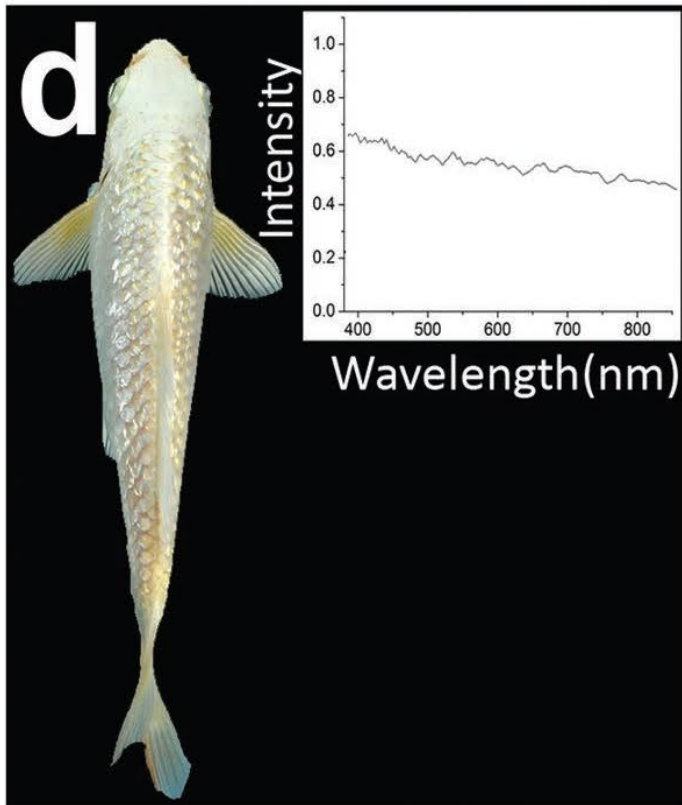
Chitin



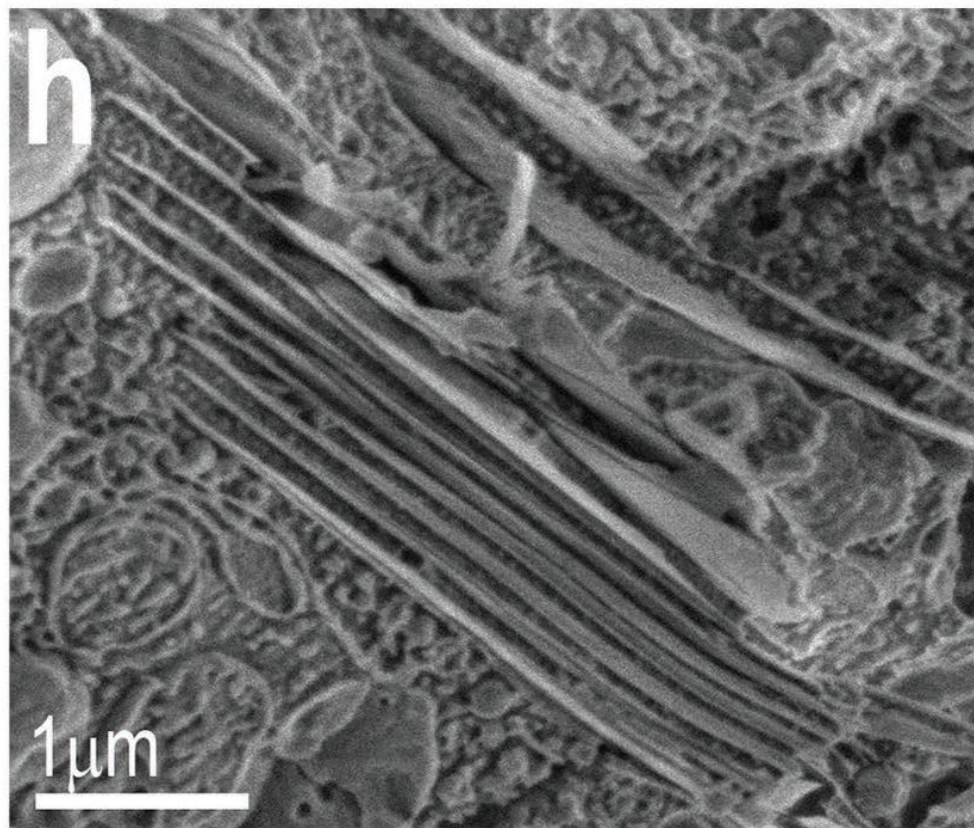
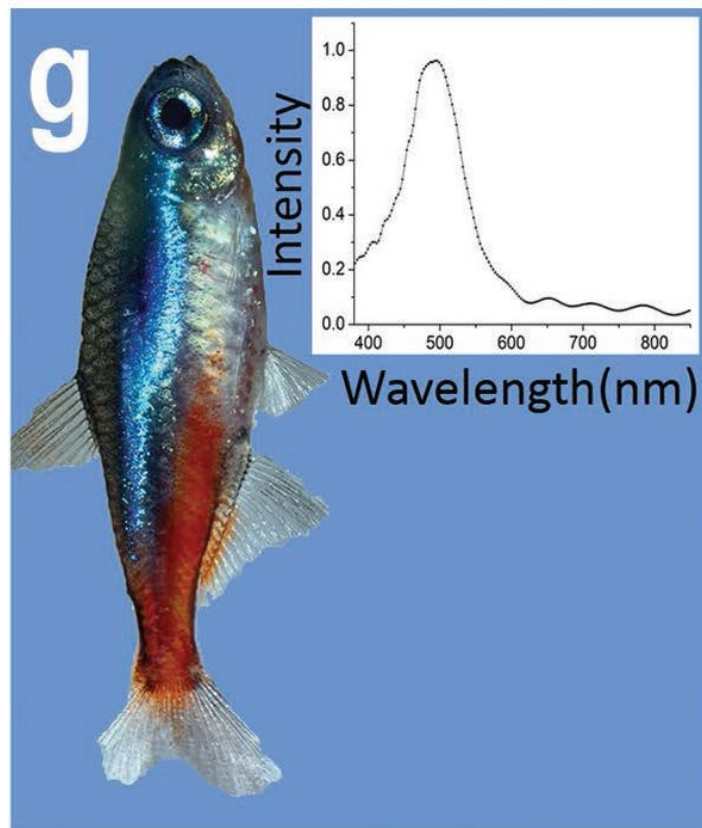
# Ultrastruktura motýlího křídla Fotonické krystaly z chitinu

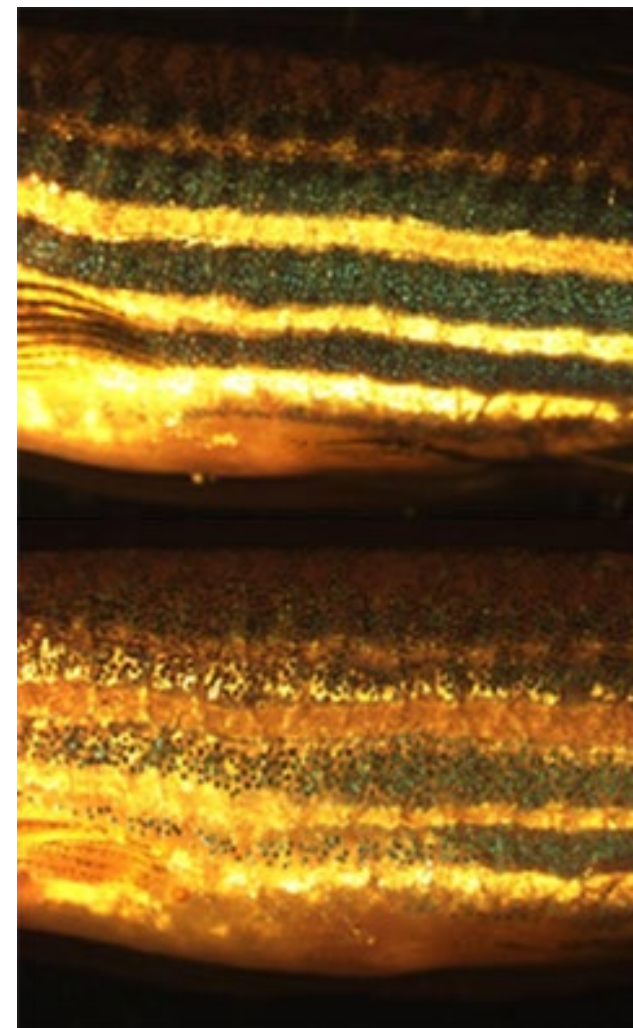
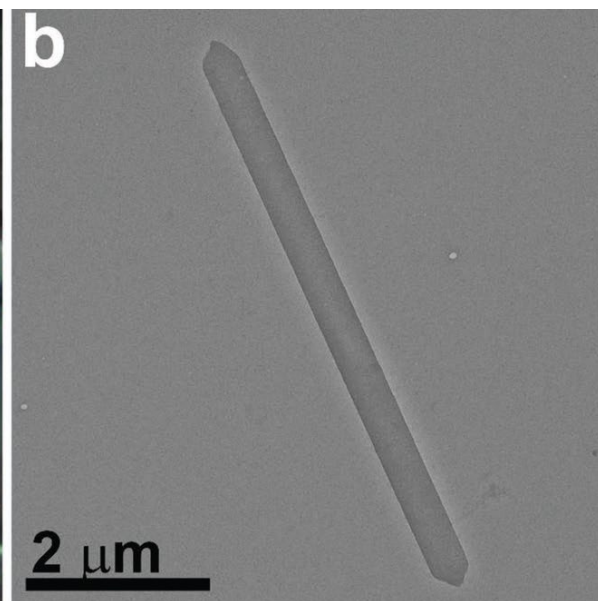
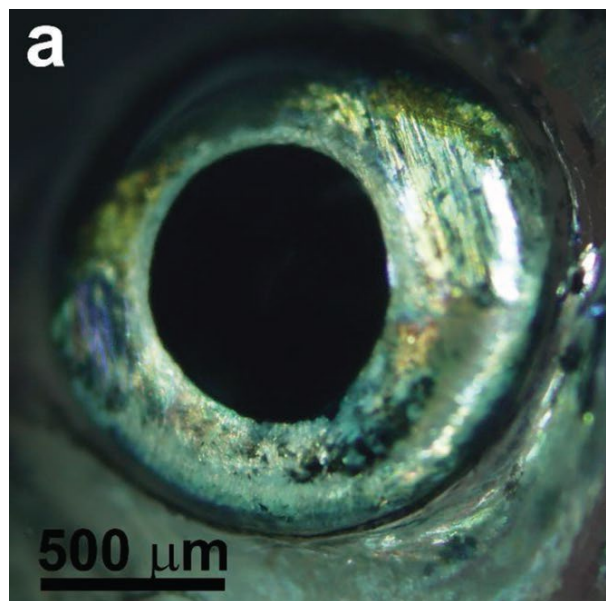


## Japonský kapr (*Cyprinus carpio*, Koi fish )

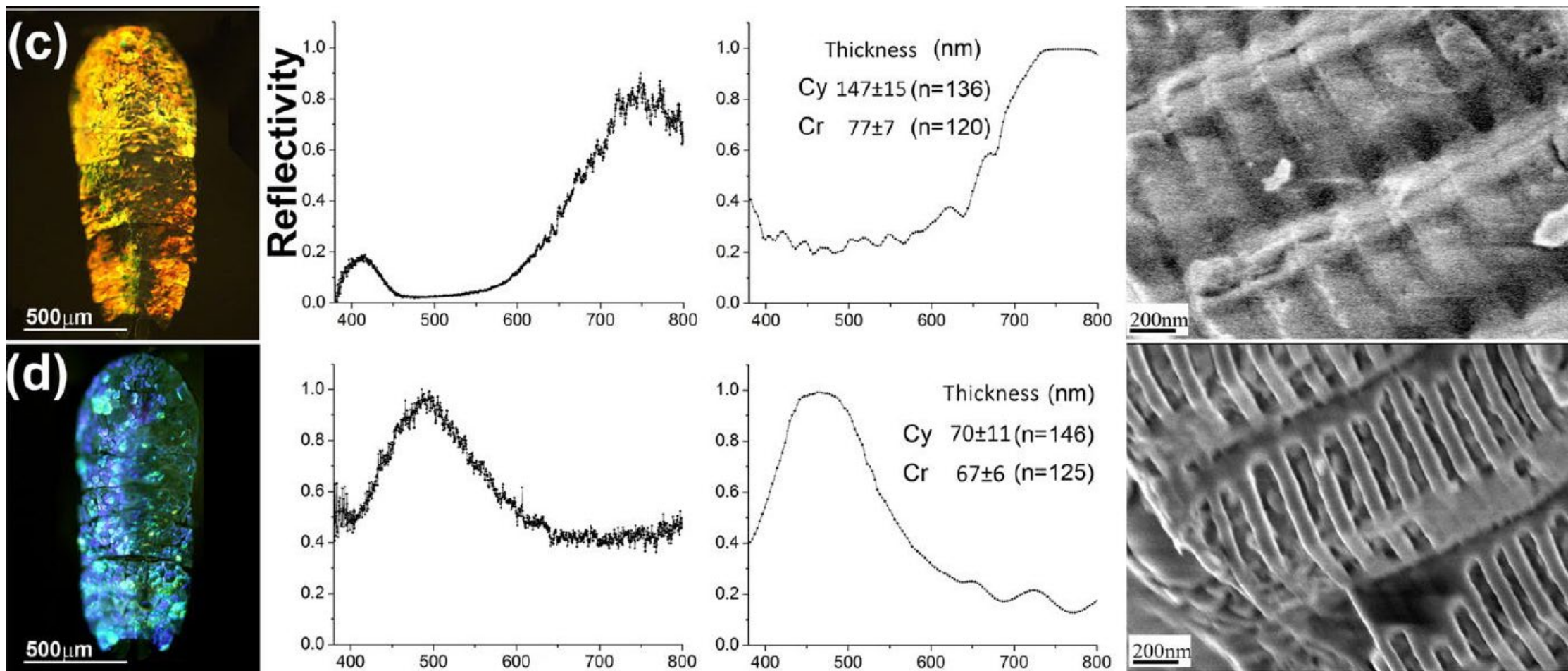


## Neonka obecná (*Paracheirodon innesi*)



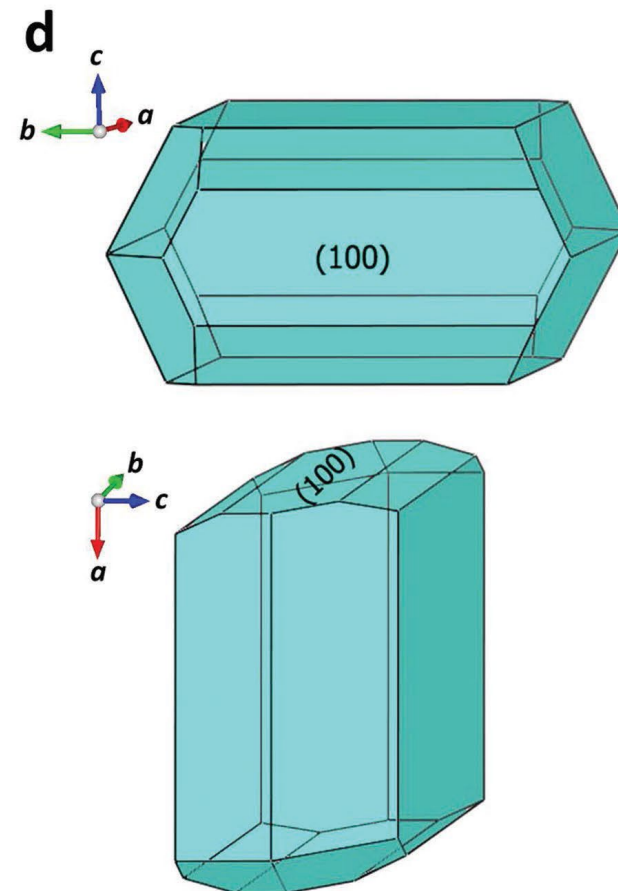
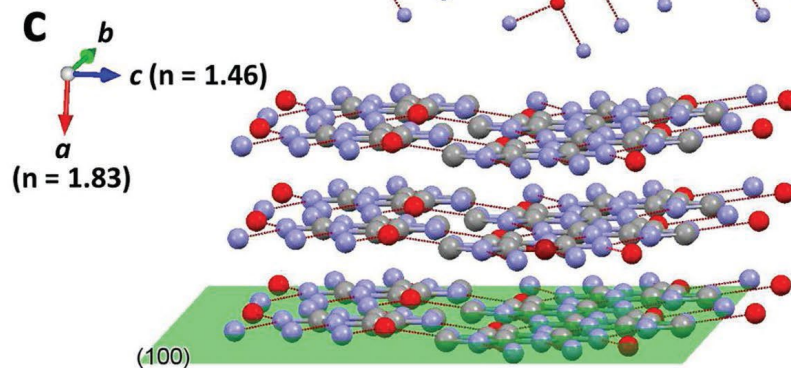
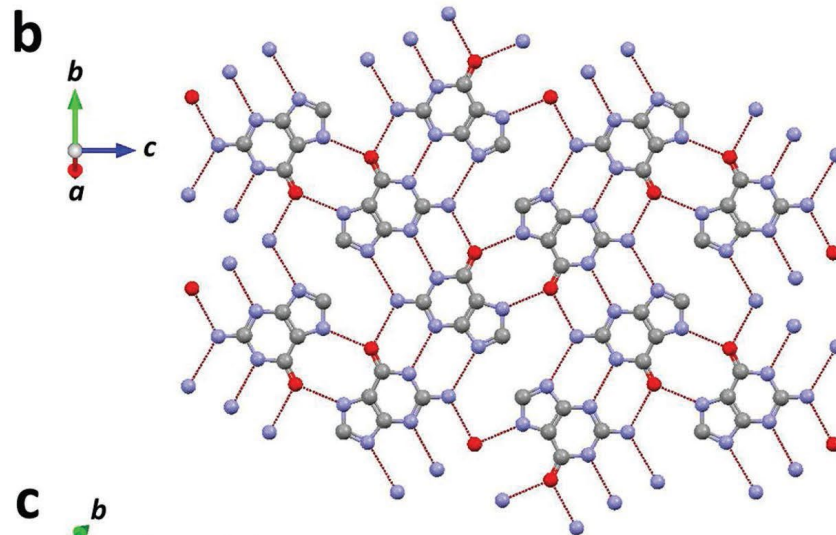
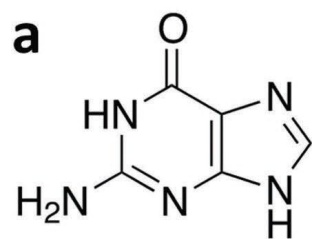


Dánio pruhované (*Danio rerio*, zebrafish)



Klanonožec (Copepoda, *Sapphirina metallina*)

# Krystalický guanin



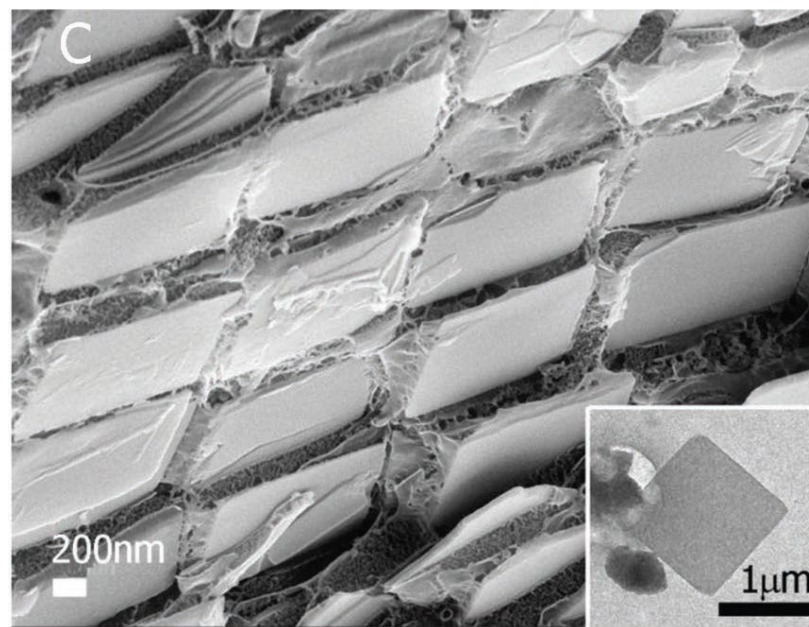
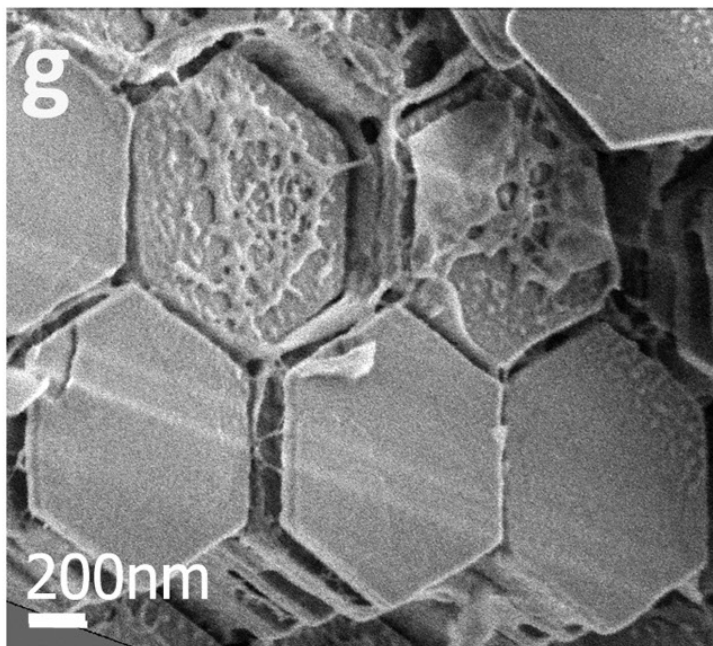
dvojlomný materiál:

ve směru os **b** a **c**:  $n = 1.46$

ve směru osy **a**:  $n = 1.83$

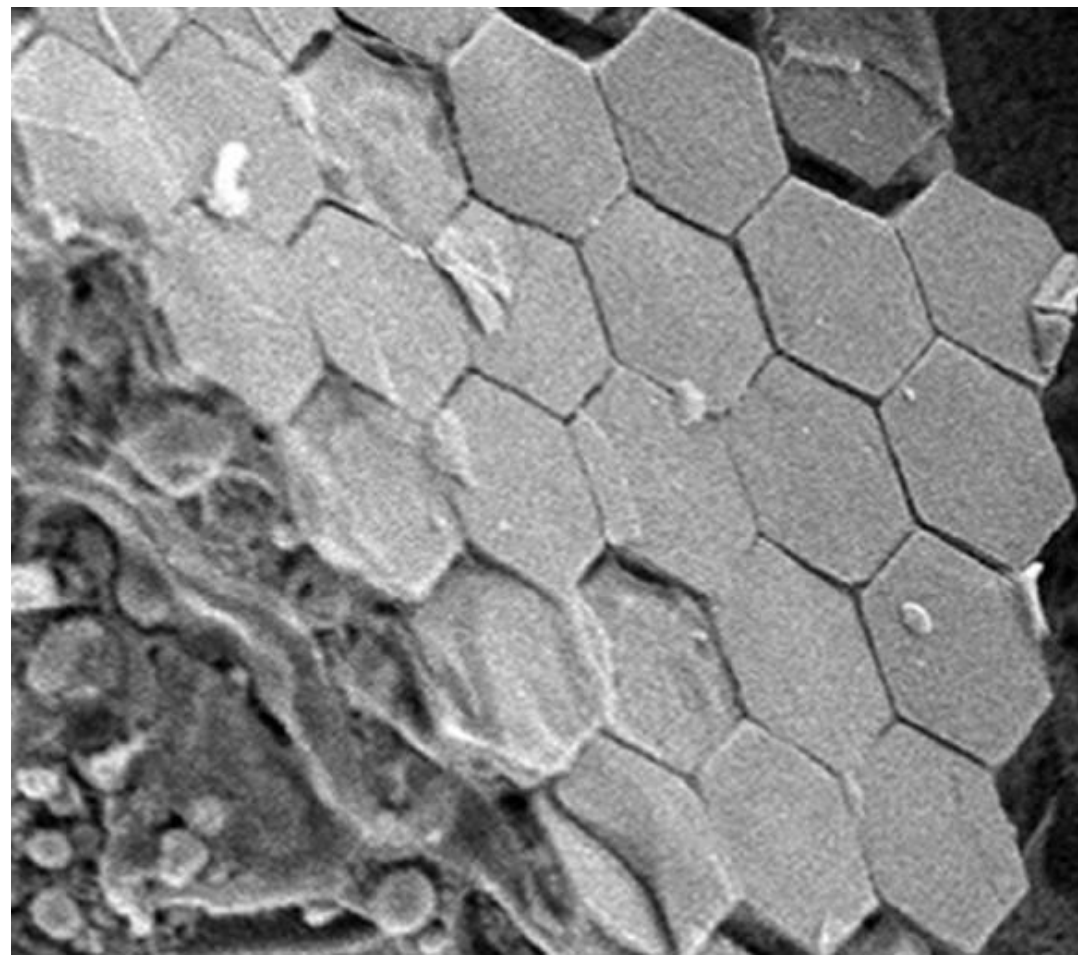
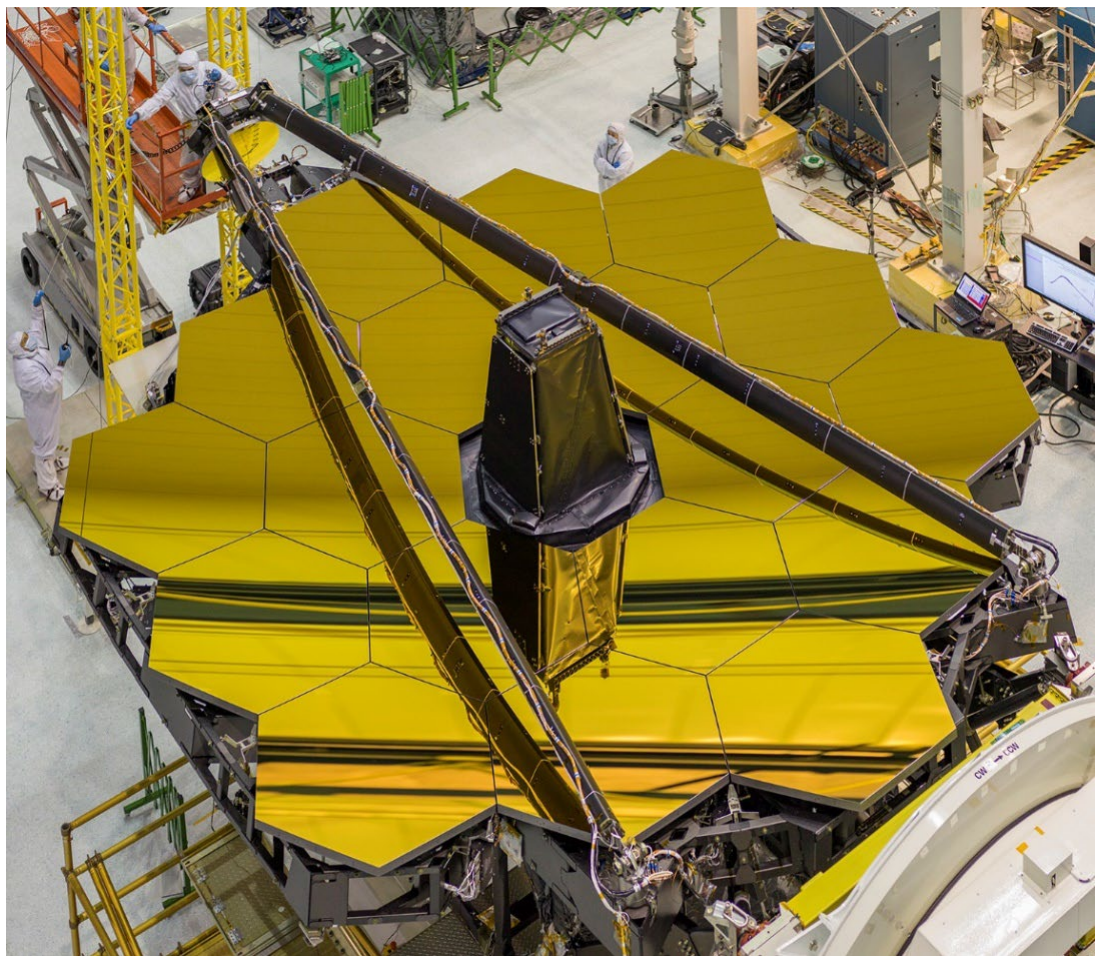


*Tapetum lucidum* z krystalického guaninu



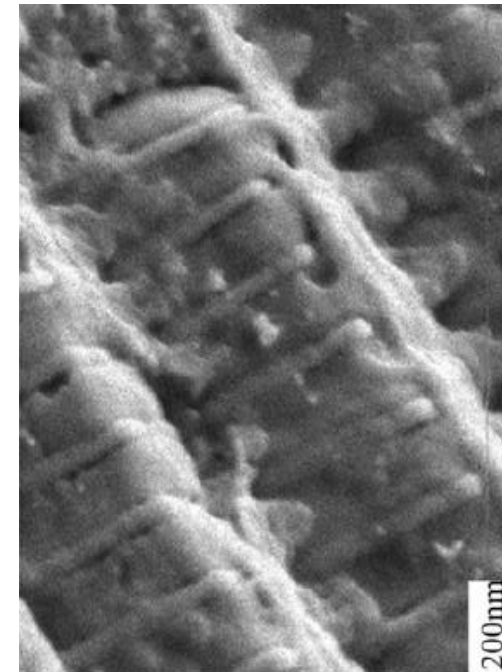
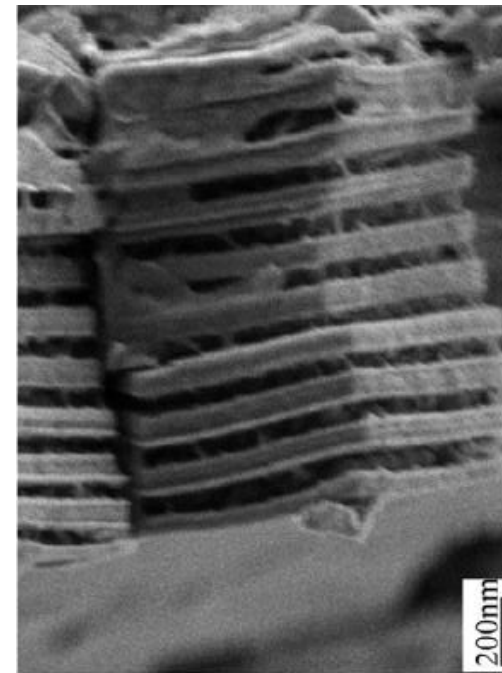
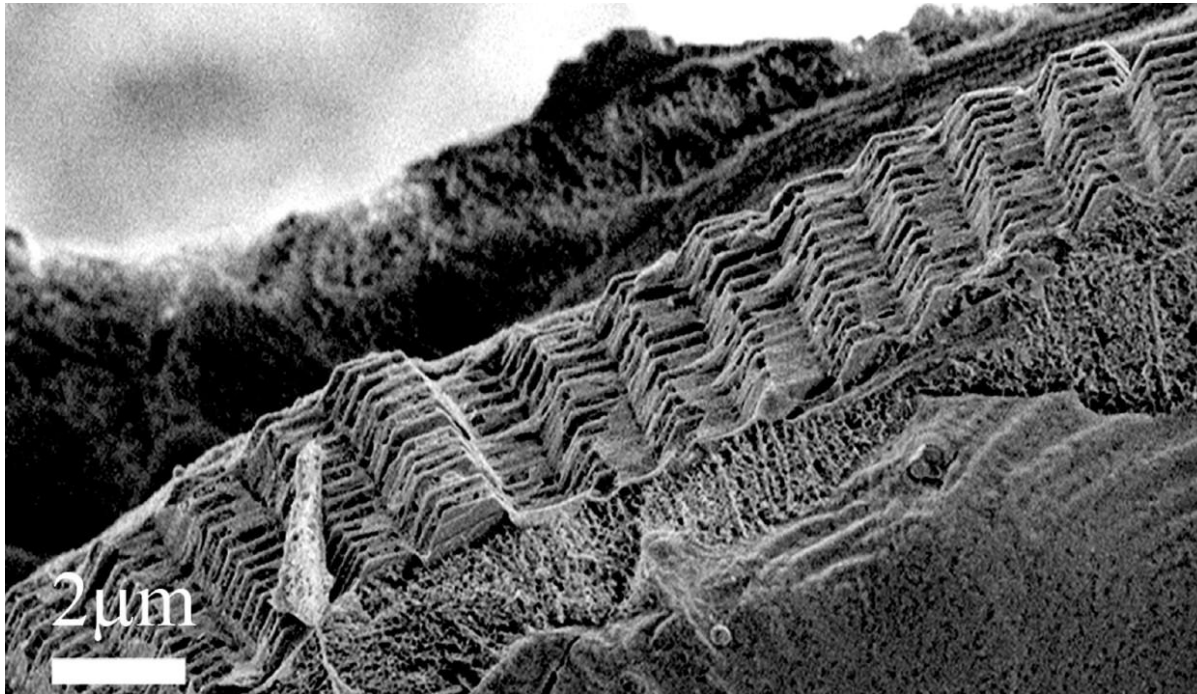
Klanonožec (Copepoda, *Sapphirina metallina*)

Hřebenatka (*Pecten maximus*)

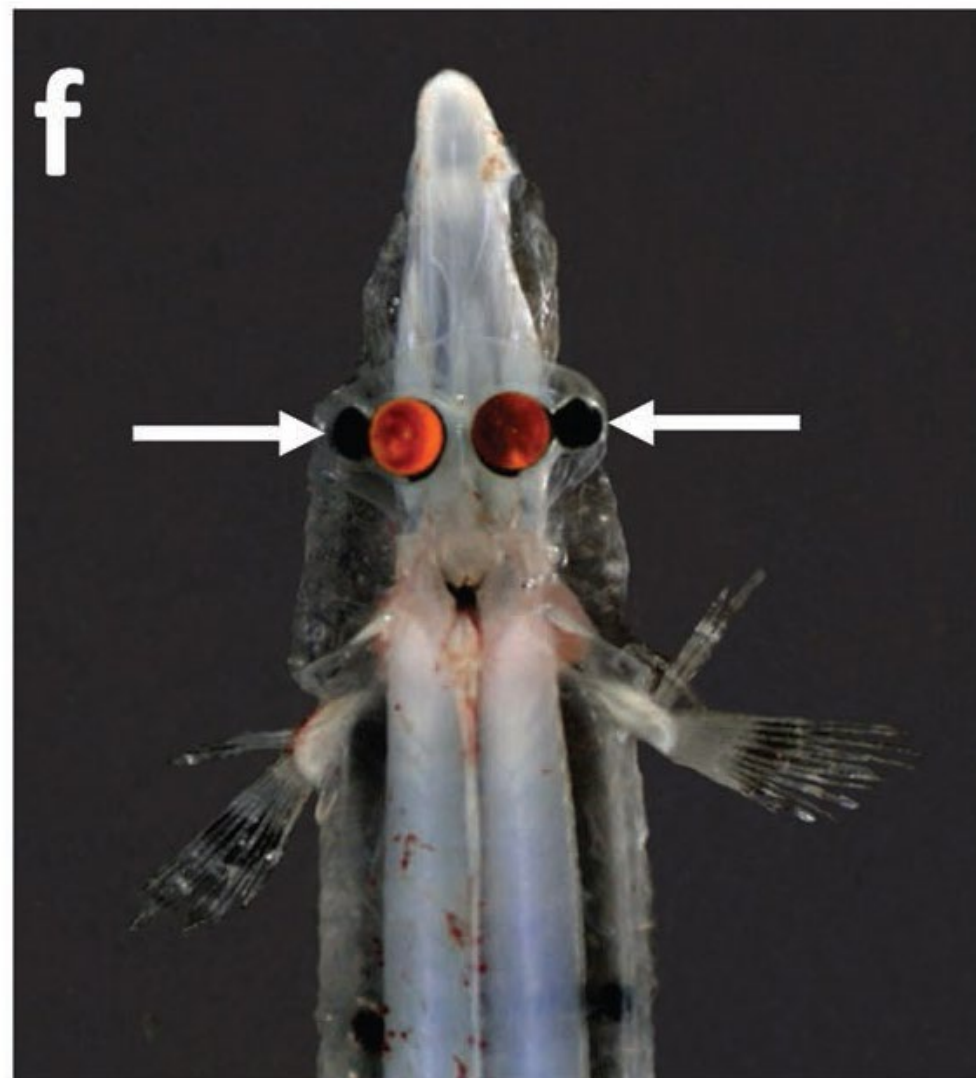
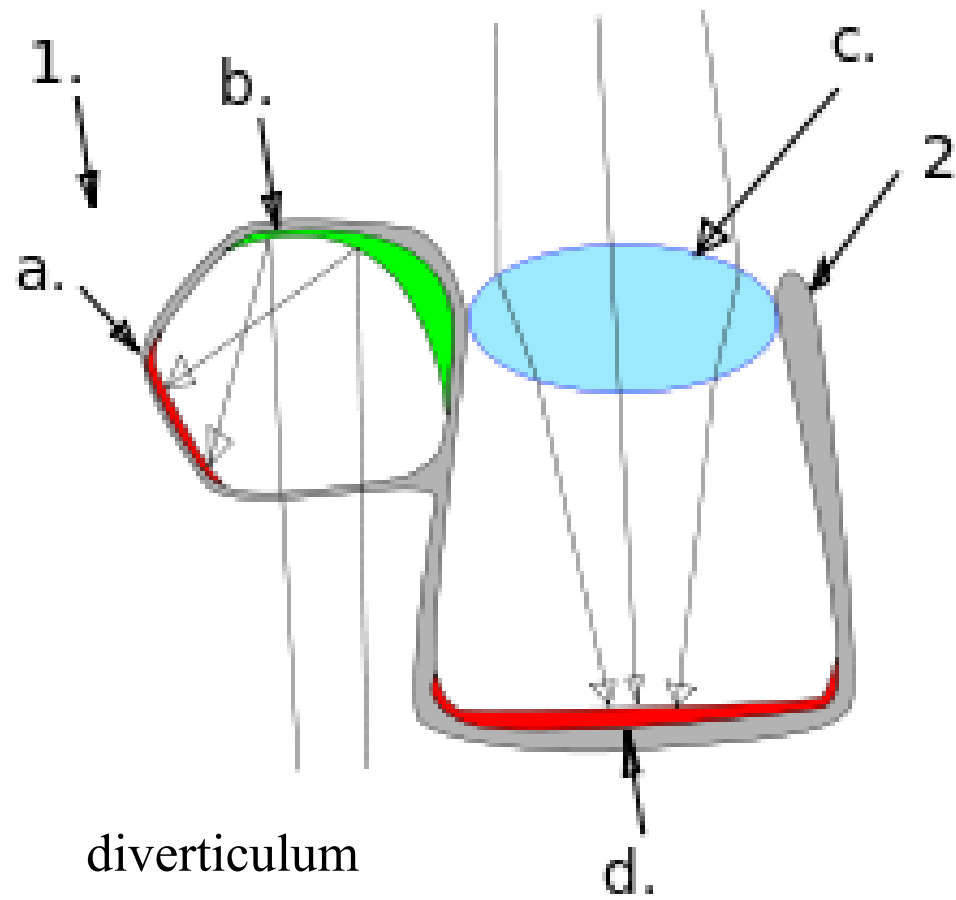


**Inspirace?**

$$|R|^2 = \left| \frac{1 - \left(\frac{n_h}{n_l}\right)^{2N}}{1 + \left(\frac{n_h}{n_l}\right)^{2N}} \right|^2$$



# Strašík hnědorypý (*Dolichopteryx longipes*)



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