Q

Lasers: Pew! Pew!

What does the acronym **LASER** *stand for?*

L	***A***	***S***	***E***	***R***

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Light Amplification by Stimulated Emission of Radiation

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Frequency of the light

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They are all the names of lasers commonly employed in ophthalmology (lasers are often named after their active medium)

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No, only the neodymium is; the other substances play a supporting role

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tl;dr The shorter the pulse, the greater the power per pulse

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Take-home points: One can increase the power of a laser by increasing the frequency of the emitted light, and/or by shortening the pulse-time

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As an important aside: What other step can be taken to increase the intensity of laser energy?

What can be done to ***get more 'bang for the buck' from a laser****?*
By releasing the energy over a very brief period of time, the laser's **power** (power = energy/time) can be ramped up

A

Lasers: Pew! Pew!

In clinical optics, we think of light almost exclusively as waves traveling in a given direction (usually represented by a ray). Does this model suffice to understand lasers?
Unfortunately no—understanding lasers obligates us to consider light as being comprised of particle(-like) entities called **photons**

OK, what are photons*?*
Think of photons as being little packets of light emitted by electrons . In a ludicrously oversimplified nutshell: When an electron jumps from a higher-energy orbit to a lower-energy one, it releases ('radiates') a photon that carries the excess energy. And when that photon strikes *another* electron, it imparts the energy to the second electron, causing it to jump to a higher-energy orbit.

As an important aside: What other step can be taken to increase the intensity of laser energy?
Reduce the size of the area to which the laser is being applied; ie, concentrate/focus the laser energy on a smaller area

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*We saw that power is 'energy over time.' Now we're talking about '*energy over **area**.*' What is the name for this variable?*

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We saw that power is 'energy over time.' Now we're talking about 'energy over **area**.' *What is the name for this variable?*
Fluence = energy/area. (We will soon see that one laser procedure is known for being 'low fluence.')

*What can be done to **get more 'bang for the buck' from a laser**?*
By releasing the energy over a very brief period of time, the laser's **power** (power = energy/time) can be ramped up

Q

Lasers: Pew! Pew!

What is the essence of laser-tissue interaction?

A

Lasers: Pew! Pew!

What is the essence of laser-tissue interaction?

It boils down to transferring the energy emitted by the laser to the target tissue

Q

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What factors influence the transference of energy?

A

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There are two categories of factors affecting laser-energy transfer:

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Laser-related factors

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- ?
- ?

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- Composition
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- ***?***
- ***?***
- ***?***

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***Laser*-related factors**
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- Power
- Fluence

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- Power

What is a **chromophore** *in this context?*

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*What is a **chromophore** in this context?*
A molecule that absorbs light of a certain wavelength in a manner that results in the generation of heat (ie, a dye)

Q

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Hemoglobin and **melanin**

Q

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What two naturally-occurring **chro**

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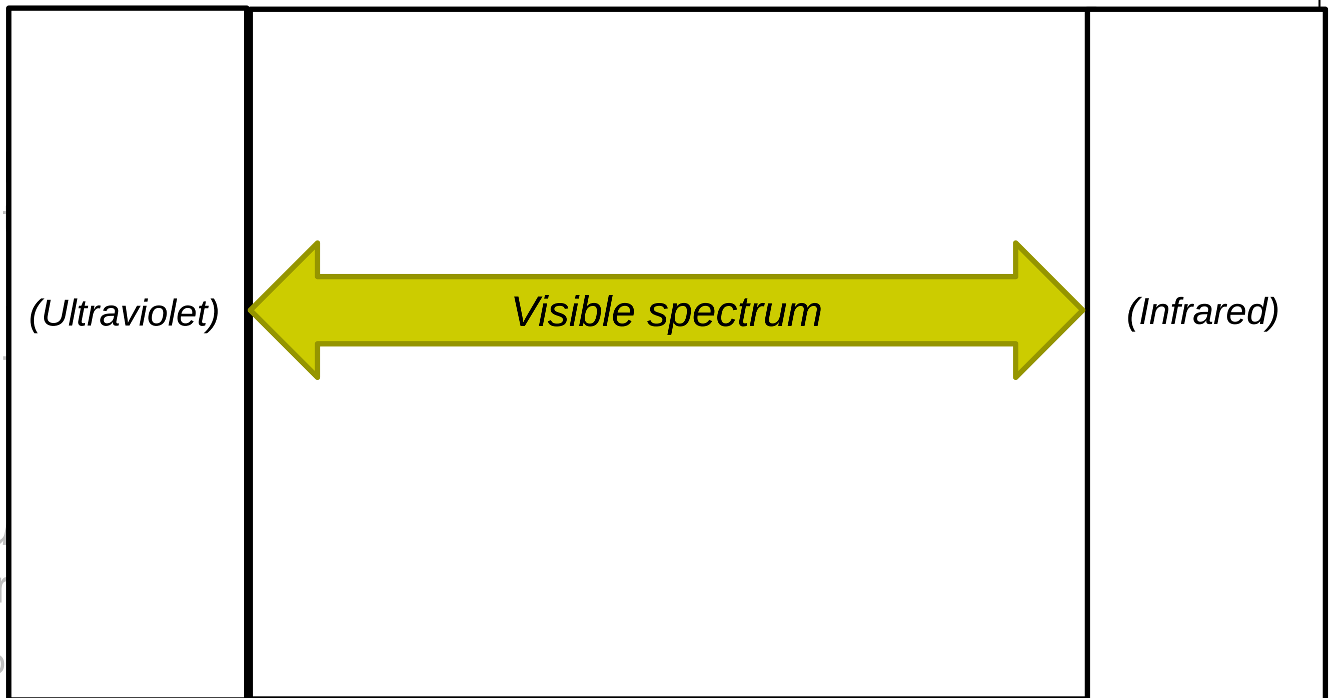
Xanthophyll

(Note: The latest iteration of the *Retina* book also refers to xanthophyll as "oxygenated carotenoids, in particular lutein and zeaxanthin")

Q

Lasers: Pew! Pew!



Tissu
factor

Co

Chromophore ? Wavelength (nm) ?

With regard to wavelength: The visible spectrum runs from what to what?

What is a **chrom**
A molecule that a
a manner that re

What two naturally-occurring **chro**
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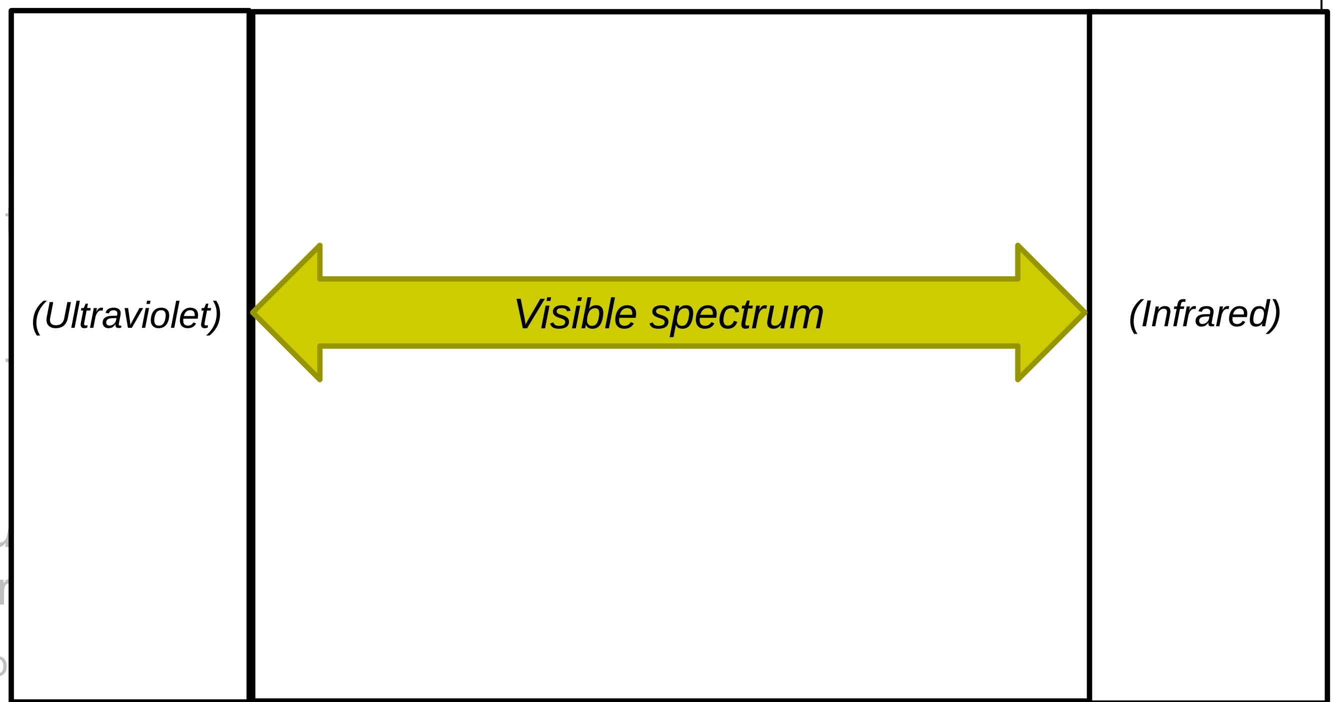

Tissu
factor
Co
Chromophore

400 Wavelength (nm) **700**

With regard to wavelength: The visible spectrum runs from what to what?
About 400 to 700 nm

What is a **chrom**
A molecule that a
a manner that re

What two naturally-occurring **chro**
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Hemoglobin and **melanin**

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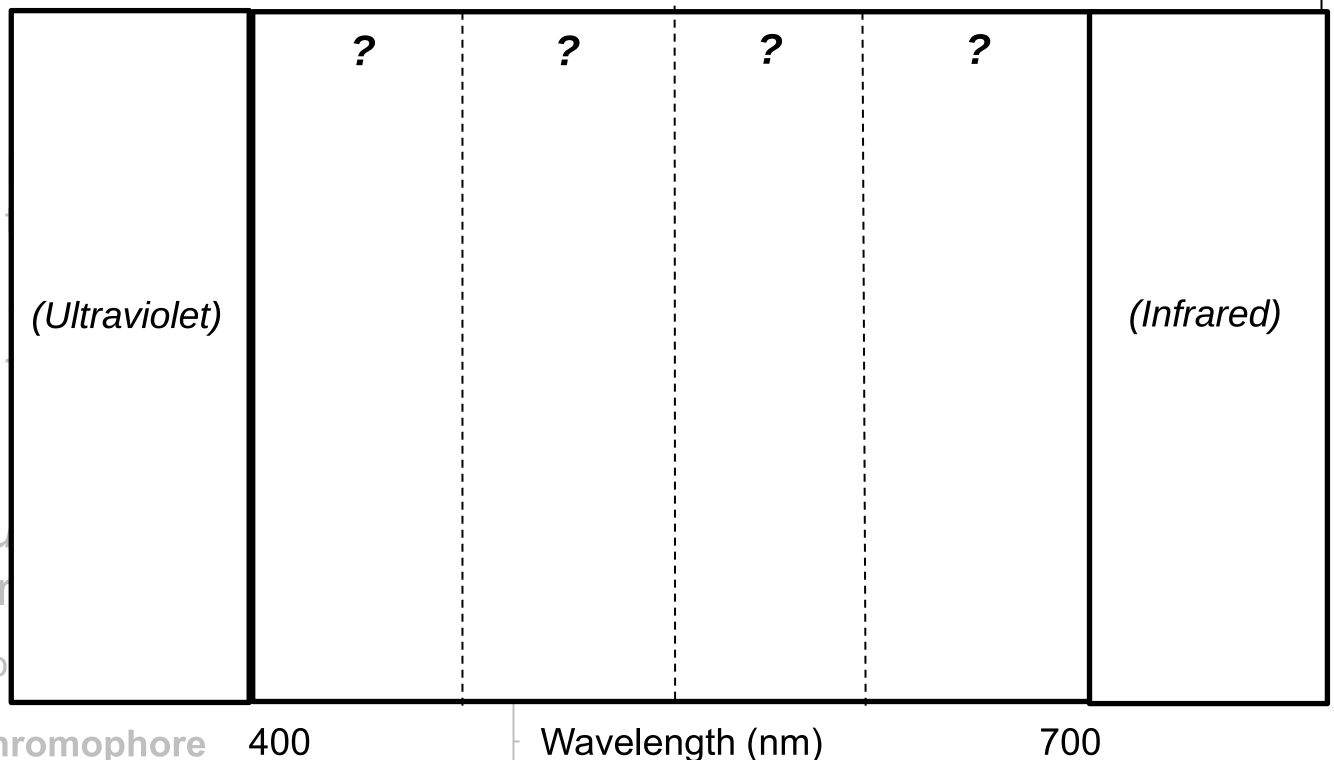

Tissu
factor
Co
Chromophore

For purposes of understanding lasers, we can divide the visible spectrum into four color segments. What are they?

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A molecule that a
a manner that re

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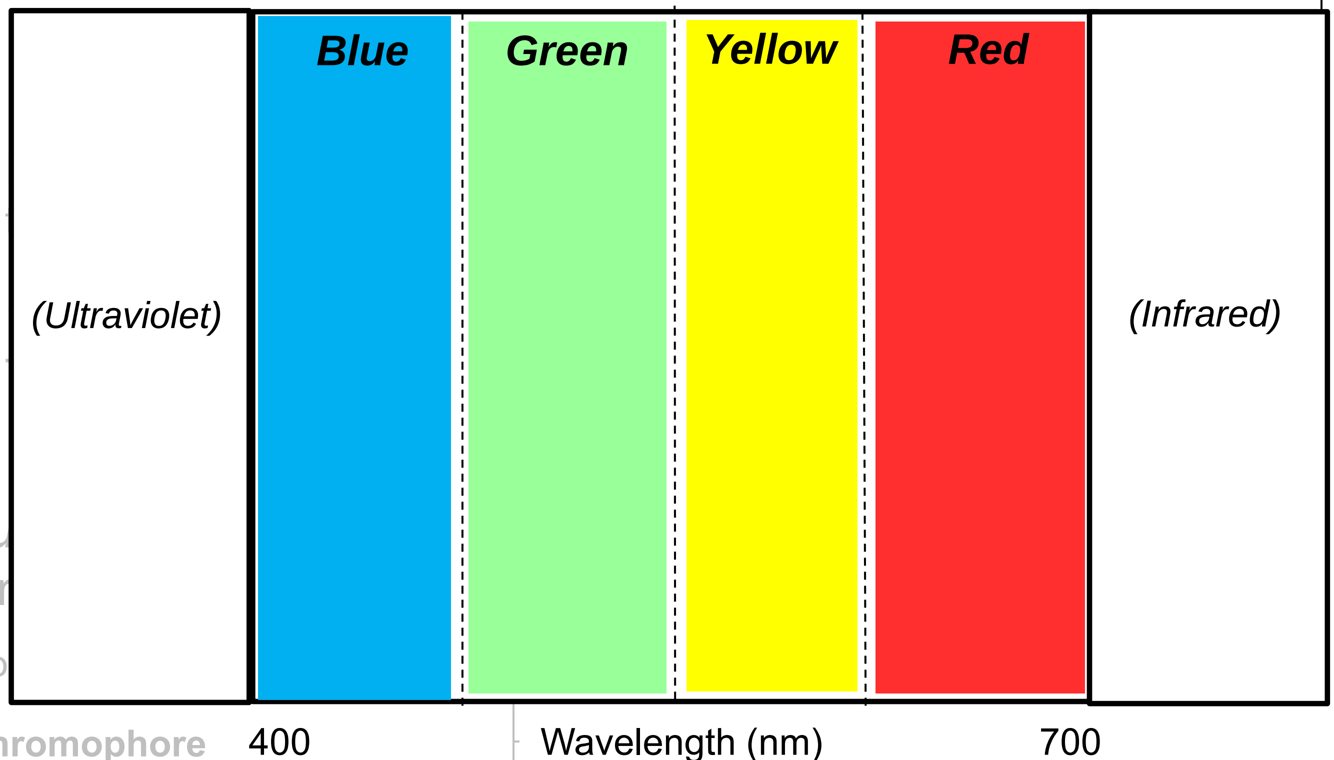

Tissu
factor
Co
Chromophore

For purposes of understanding lasers, we can divide the visible spectrum into four color segments. What are they?
Blue, **green**, **yellow**, **red**

What is a **chrom**
A molecule that a
a manner that re

What two naturally-occurring **chro**
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Hemoglobin and **melanin**

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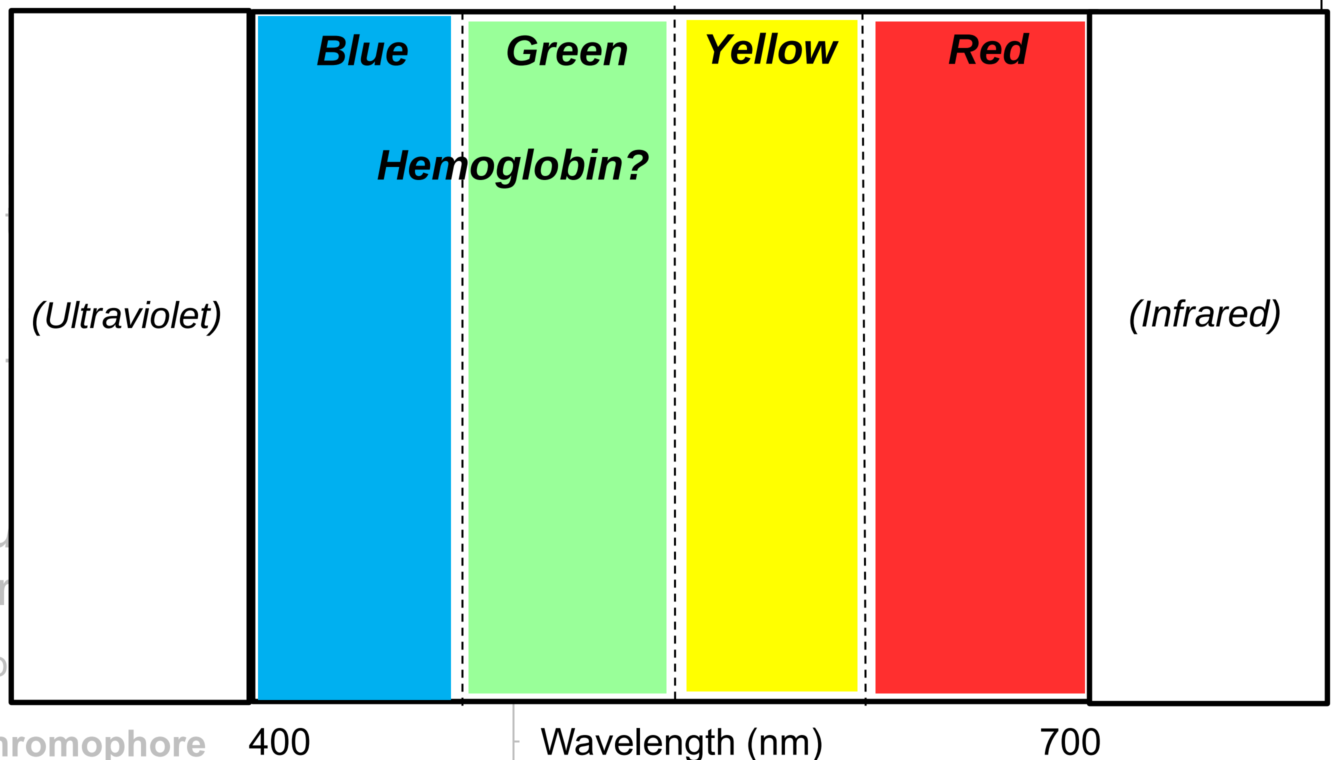
Q

Lasers: Pew! Pew!



Tissu
factor
Co
Chromophore

Which portion of the visible spectrum is well absorbed by: ***Hemoglobin****?*

What is a **chrom**
A molecule that a
a manner that re

What two naturally-occurring **chro**
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Hemoglobin and **melanin**

There is another ***chromophore****, found only in the macula, we should mention. What is it?*
Xanthophyll

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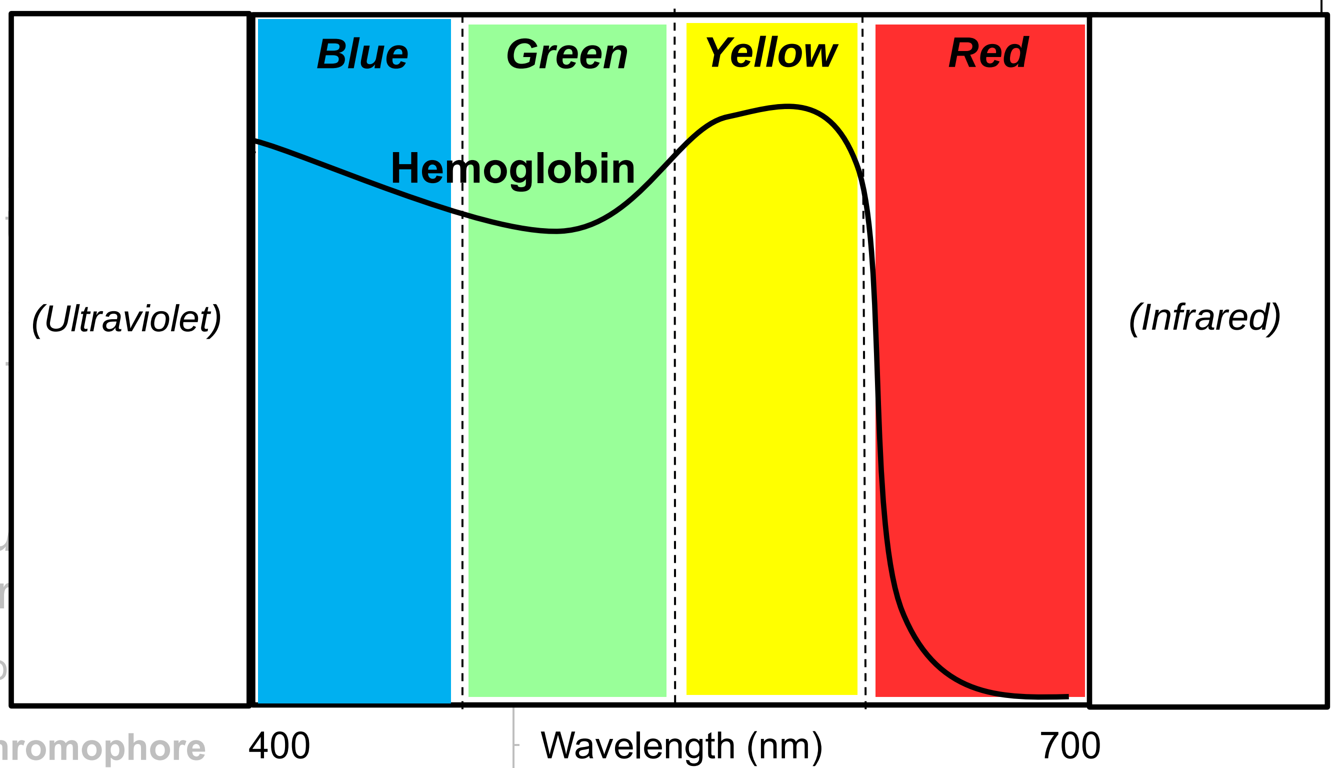
A

Lasers: Pew! Pew!



Tissu
factor
Co
Chromophore

Which portion of the visible spectrum is well absorbed by:
Hemoglobin*?* **Everything but red**

What is a **chrom**
A molecule that a
a manner that re

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the eye are exploited in ophthalm
Hemoglobin and **melanin**

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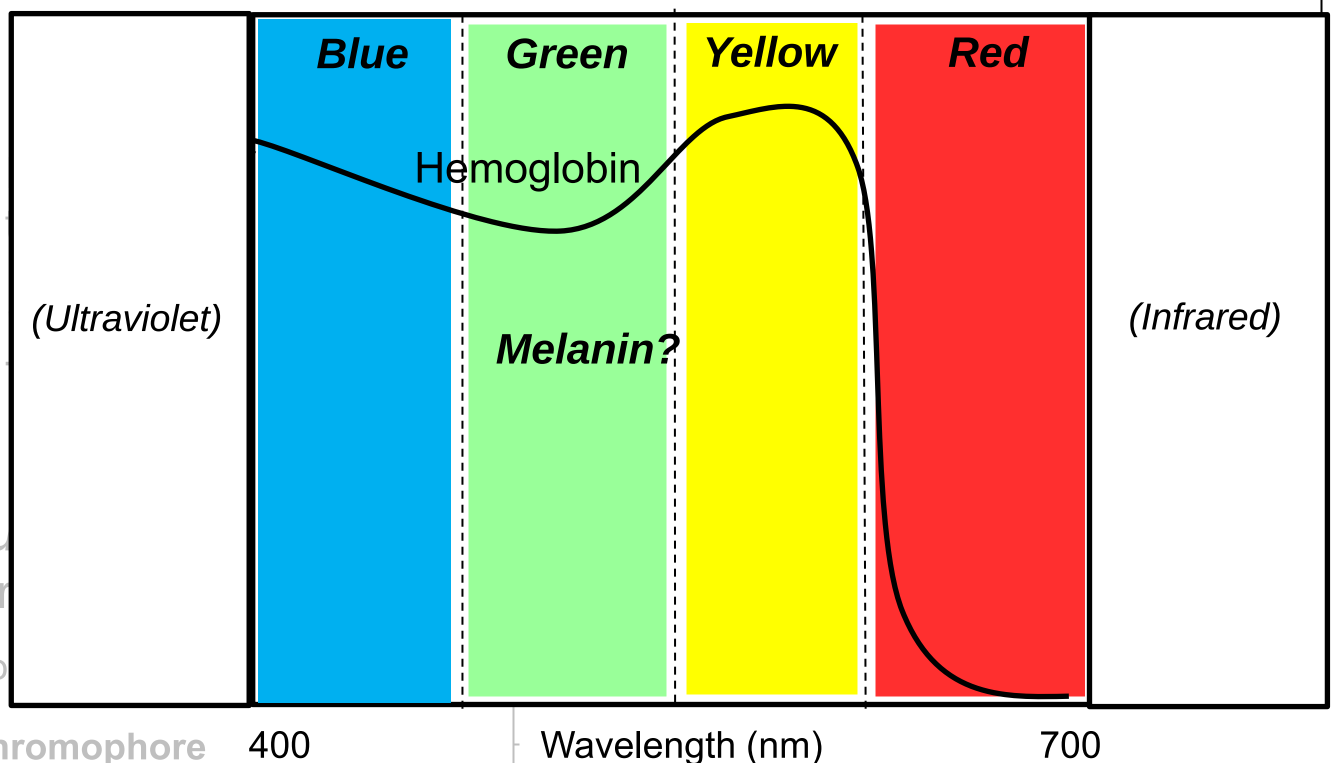
Q

Lasers: Pew! Pew!



Tissu
factor
Co
Chromophore

Which portion of the visible spectrum is well absorbed by: ***Melanin***?

What is a **chrom**
A molecule that a
a manner that re

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Hemoglobin and **melanin**

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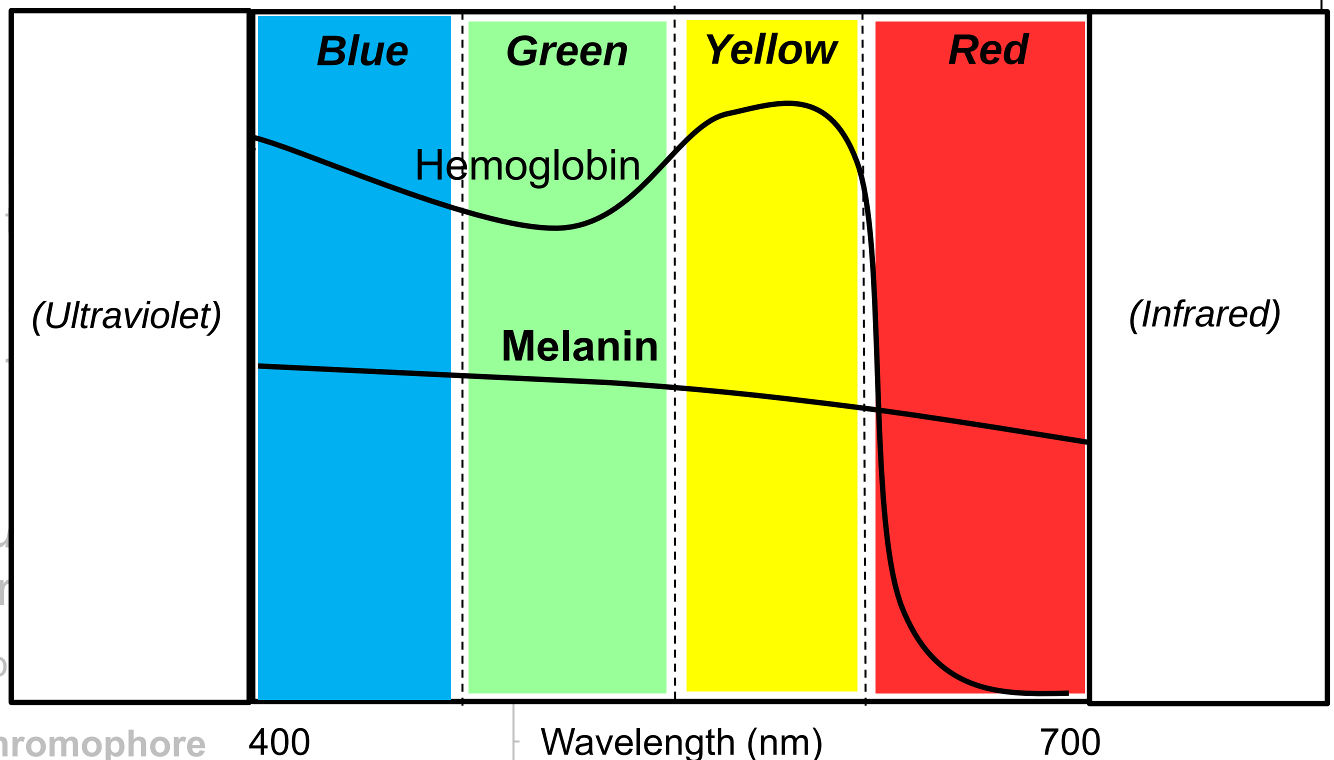
A

Lasers: Pew! Pew!



Tissu
factor
Co
Chromophore

Which portion of the visible spectrum is well absorbed by:
Melanin*?* **Everything is absorbed fairly well**

What is a **chrom**
A molecule that a
a manner that re

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Hemoglobin and **melanin**

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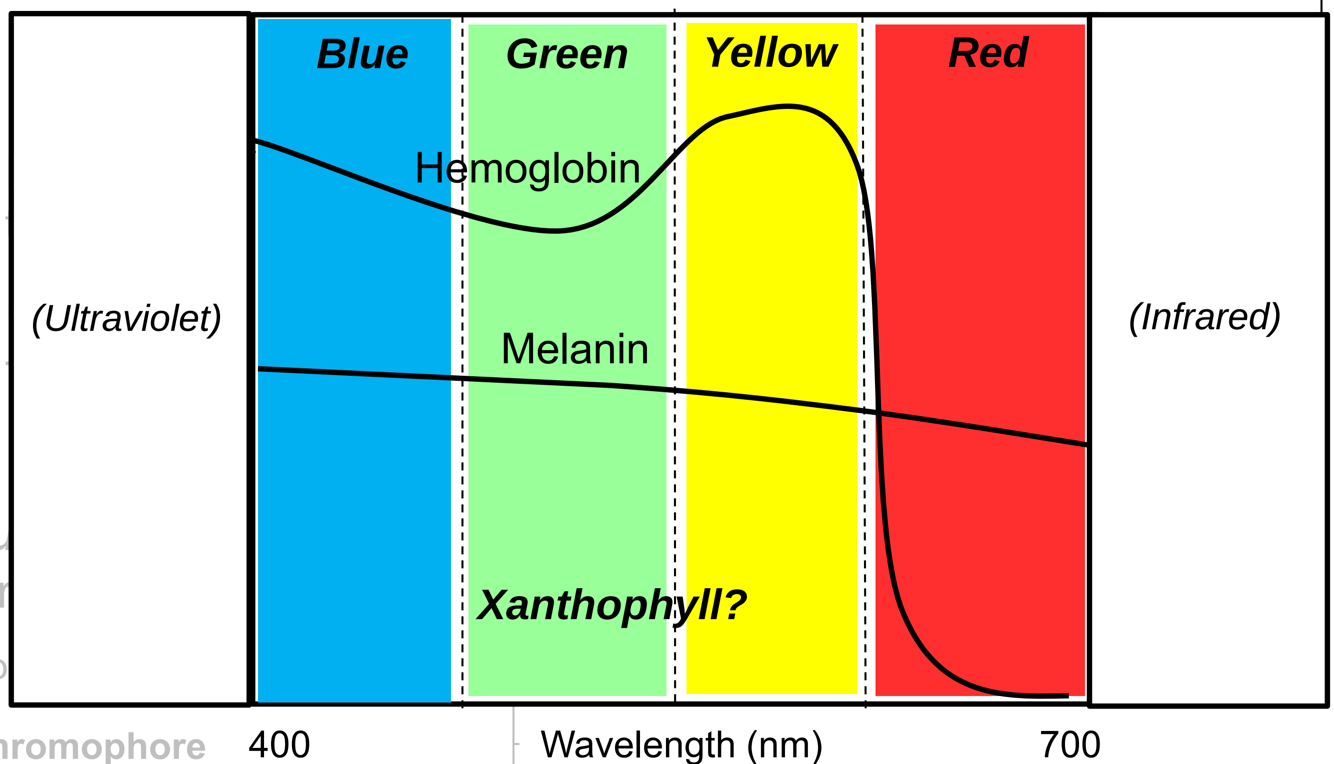

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A molecule that a
a manner that re

What two naturally-occurring **chro**
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Hemoglobin and **melanin**

Which portion of the visible spectrum is well absorbed by: Xanthophyll?

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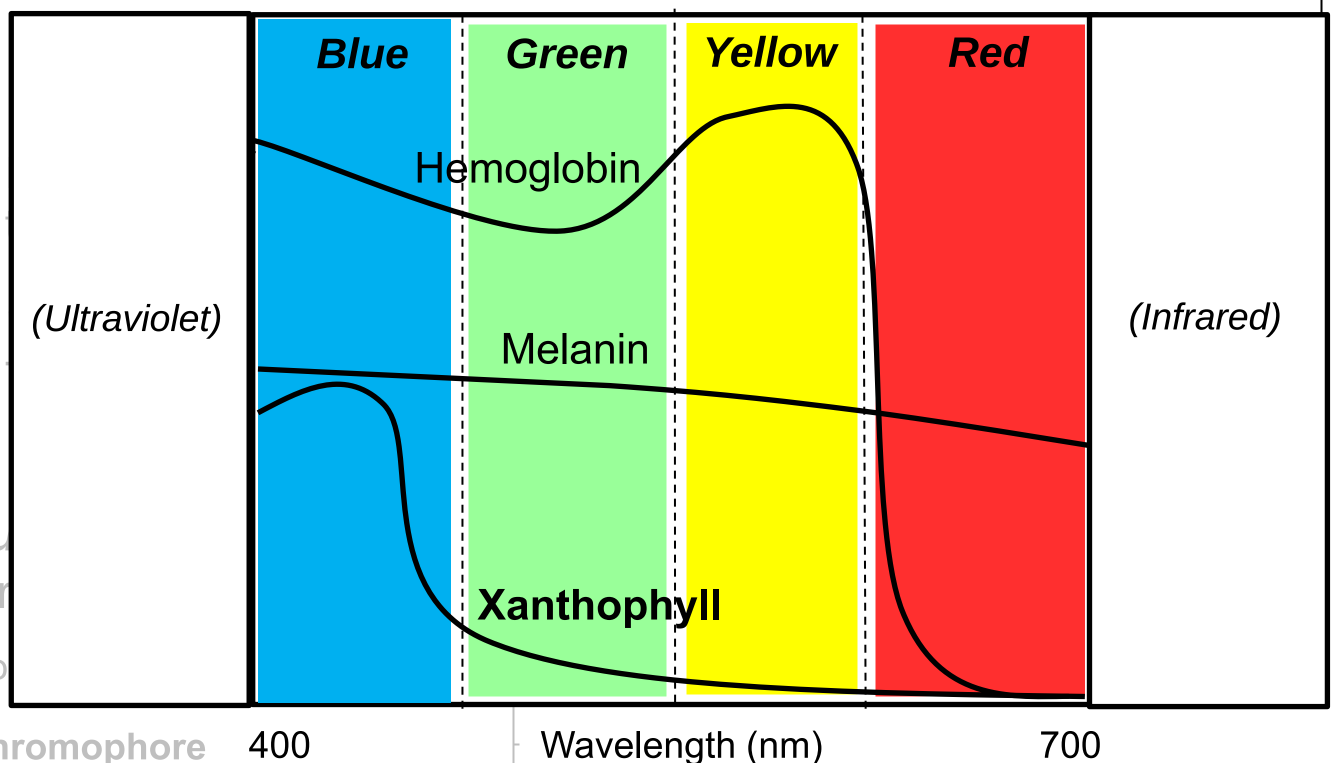

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Chromophore

Which portion of the visible spectrum is well absorbed by:
Xanthophyll? **Only blue**

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Lasers: Pew! Pew!

What is the essence of laser-tissue interaction?

It boils down to transferring the energy emitted by the laser to the target tissue

What factors influence the transference of energy?

There are **two categories** of factors affecting laser-energy transfer:

Tissue-related factors
- Composition
- Chromophores

Laser-related factors
- Energy
- Power = Energy/time
- Fluence = Energy/area

We've seen that power is energy per unit time, and fluence is energy per unit area. Is there any way to put this all together as a single factor?

Q/A

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$$? = \frac{\text{Power}}{\text{Area in cm}^2}$$

We've seen that power is energy per unit time, and fluence is energy per unit area. Is there any way to put this all together as a single factor?

Indeed there is. A laser's ________ is defined as its **power per unit area** (usually in cm^2)

A

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FYI, another name for 'intensity' is two words

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Power density ~~Intensity~~ $= \dfrac{\text{Power}}{\text{Area in cm}^2}$

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Indeed there is. A laser's **intensity** is defined as its **power per unit area** (usually in cm^2)

FYI, another name for 'intensity' is *power density* (which makes sense, as the factor is 'power per something')

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A final FYI on the same subject: Still another name for 'intensity' and 'power density' is one word

A

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Irradiance ~~Power density~~ ~~Intensity~~ = $\frac{\text{Power}}{\text{Area in cm}^2}$

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A final FYI on the same subject: Still another name for 'intensity' and 'power density' is *irradiance*

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Irradiance ~~Power density~~ ~~Intensity~~ = $\frac{\text{Power}}{\text{Area in } \mathbf{m^2}}$

We've seen that power is energy per unit time, and fluence is energy per unit area. Is there any way to put this all together as a single factor?

Indeed there is. A laser's **intensity** is defined as its **power per unit area** (usually in cm^2)

A final FYI on the same subject: Still another name for 'intensity' and 'power density' is *irradiance* (with the stipulation that irradiance employs area in $\mathbf{m}^2$, not cm^2)

Lasers: Pew! Pew!

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$$\textit{Intensity} = \frac{\text{Power}}{\text{Area in cm}^2}$$

=

Note that because power = energy/time, *intensity* can be written thusly:

$$\textit{Intensity} = \frac{\frac{\text{Energy}}{\text{Time}}}{\text{Area in cm}^2}$$

Indeed there is. A laser's "**intensity**" is d

(usually in cm^2)

Lasers: Pew! Pew!

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$$\textit{Intensity} = \frac{\frac{\text{Energy}}{\text{Time}}}{\text{Area in cm}^2}$$

Indeed there is. A laser's "intensity" is d

(usually in cm²)

Which can be rewritten as:

$$\textit{Intensity} = \frac{\text{Energy}}{\text{Time x area}}$$

Lasers: Pew! Pew!

What is the essence of laser-tissue interaction?

It boils down to transferring the energy emitted by the laser to the target tissue

What factors influence the transference of energy?

There are **two categories** of factors affecting laser-energy transfer:

***Tissue*-related factors**
- Composition
- Chromophores

***Laser*-related factors**
- Energy
- Power = Energy/time
- Fluence = Energy/area

$$\textit{Intensity} = \frac{\text{Power}}{\text{Area in cm}^2}$$

$$\textit{Intensity} = \frac{\text{Energy} / \text{Time}}{\text{Area in cm}^2}$$

$$\textit{Intensity} = \frac{\text{Energy}}{\text{Time x area}}$$

Note th

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This formulation neatly illustrates how intensity can be increased by:
--Increasing pulse **energy**, *or*
--decreasing pulse **time**, *or*
--decreasing pulse **area**

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So commit this to memory!

$$\textit{Intensity} = \frac{\text{Energy}}{\text{Time x area}}$$

Q

Lasers: Pew! Pew!

What are the five modes of laser-tissue interaction?

? **?** **?** **?** **?**

A

Lasers: Pew! Pew!

What are the five modes of laser-tissue interaction?

Photo-chemical
aka *photoactivation*

Thermal

Photo-ablation

Plasma-induced ablation

Photo-disruption
aka *plasma-induced disruption*

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Are these thrown up here rando, or are they in an order of some sort?

Q/A

Lasers: Pew! Pew!

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How is intensity ramped up from one mode to the next?

Q/A

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All three variables are manipulated to some extent, but probably account for the lion's share of the differences

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Briefly, what steps are involved in a photochemical laser procedure?

1)

2)

3)

4)

Q/A

Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

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3) The activated dye reacts with [element] to create [three words] which cause local [two words]
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Q/A

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4) Platelet activation produces [one word] of the lesion's vasculature.

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Photodynamic therapy (PDT)

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How much time is allowed to pass?
10 minutes

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For how long is the laser light applied to the lesion?
83 seconds

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The five modes of laser-tissue interaction:

Before the next PDT question…What does PRP *stand for in this context?*

Plasma-induced ablation

Photo-disruption

aka plasma-induced disruption

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PRP laser

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Panretinal photocoagulation

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Several thousand laser burns are placed throughout the retinal periphery

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Q

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1) A **photosensitizing dye** is injected intravenously, and time sufficient to allow concentration of the dye in the target lesion is allowed to pass

Why doesn't the PDT laser cause thermal damage like, say, a PRP laser does?

intraocular tumors.

A

Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

Photo-chemical aka *photoactivation*

Thermal

Photo-ablation

Plasma-induced ablation

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Because the PDT laser is a low fluence laser, whereas PRP employs a high fluence laser.

Fluence = Energy/area

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The tx area (ie, spot size) in PRP is measured in microns, whereas the tx area in PDT is measured in centimeters. Thus, for a given amount of energy delivered, the fluence of PRP is orders of magnitude higher than the fluence of PDT.

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Briefly, what steps are involved in a photochemical laser procedure?

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Of course, another reason PDT doesn't produce thermal effects like PRP is because the PDT laser is a low power laser, whereas PRP employs a high power laser.

Power = Energy/time

The tx time in PRP is measured in ms, whereas the tx time in PDT is measured in seconds. Thus, for a given amount of energy delivered, the power of PRP is orders of magnitude higher than the power of PDT.

intraocular tumors.

Lasers: Pew! Pew!

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Note: All PDT is of low fluence compared to most other laser procedures. However, there is a PDT variant called *low-* or *half-fluence PDT* in which the amount of energy delivered is half of the standard PDT dose (there is some evidence that half-fluence PDT is more effective than full-fluence)

Wh
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$$\text{half-Fluence} = \frac{\text{Energy/area}}{2}$$

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Couldn't you produce half-fluence by doubling the denominator instead of halving the numerator?
Well, you *could*, but doing so wouldn't be prudent. In PDT, we're treating a lesion of a certain size/extent. It would make no therapeutic sense to reduce fluence by doubling the treatment area, because this would entail 'treating' the healthy tissue surrounding the lesion.

Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

Photo-chemical	Thermal	Photo-ablation	Plasma-induced ablation	Photo-disruption
aka *photoactivation*				aka *plasma-induced disruption*
Very-low-power laser energy causes a photosensitive dye to undergo chemical rxn				
PDT				

No question—proceed when ready

Q

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It means the protein has been forced out of its native conformation by some sort of applied stress (in this case, heat). Because a protein's function is inextricably tied to its shape, denatured proteins do not behave as they do in their native form.

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Consider egg albumin. In its native state, it's a clear liquid. But if sufficient heat is applied, it becomes a white solid. (And if sufficient salsa is applied to the white solid, it becomes delish.)

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At what temperature does retinal tissue start to coagulate?

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That's convenient, because we already know a little about PRP after comparing and contrasting it with PDT; eg, we know PRP achieves much higher intensity (aka power density, aka irradiance) by employing vastly shorter pulse times and vastly smaller target areas.

(No question yet—proceed when ready)

Q

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Both procedures employ a dye of sorts to produce the desired therapeutic effect

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two categories

***Tissue*-related factors**

- Composition
- **Chromophore**

Huh? I've seen/performed PRP, and no dye was employed. What are you talking about?
Recall an earlier slide on which it was pointed out that **chromophores** can serve as 'natural dyes.'
That is, if the incoming light is of the right wavelength, **chromophores** will absorb the energy and convert it into heat.

*What is a **chromophore** in this context?*
A molecule that absorbs light of a certain wavelength in a manner that results in the generation of heat (ie, **a dye**)

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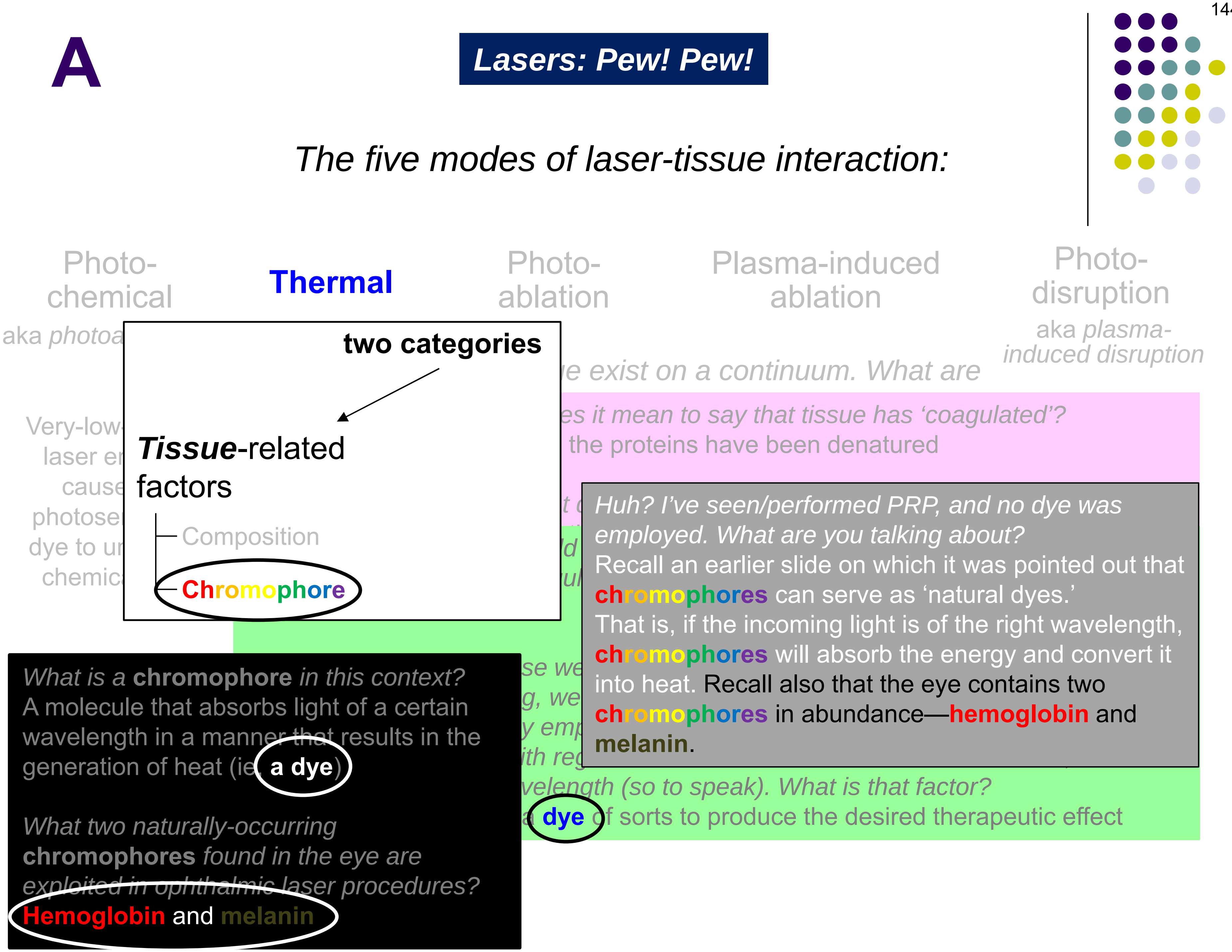
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That is, if the incoming light is of the right wavelength, chromophores will absorb the energy and convert it into heat. Recall also that the eye contains two chromophores in abundance—hemoglobin and melanin.
What is a chromophore in this context?
A molecule that absorbs light of a certain wavelength in a manner that results in the generation of heat (ie, a dye)
What two naturally-occurring chromophores found in the eye are exploited in ophthalmic laser procedures?
Hemoglobin and melanin
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The five modes of laser-tissue interaction:

(As noted earlier in the slide-set)

What wavelength of light is readily absorbed by ***hemoglobin*** *and* ***melanin****? (It's a range, BTW.)*

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At one time, only one substance was used as the active medium to produce light in the 500-580 range. (Other substances are now available.) What was that original substance?

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What wavelength of light is readily absorbed by ***hemoglobin*** *and* ***melanin****? (It's a range, BTW.)*
From 400 to 580 nm. However, wavelengths below 500 are avoided, as they are too-readily absorbed by the **xanthophyll** pigment found in the macula.

At one time, only one substance was used as the active medium to produce light in the 500-580 range. (Other substances are now available.) What was that original substance?
Argon

What color is the light produced by an argon laser?

hat

chromophores can serve as 'natural dyes.'
That is, if the incoming light is of the right wavelength, **chromophores** will absorb the energy and convert it into heat. Recall also that the eye contains two **chromophores** in abundance—**hemoglobin** and **melanin**.

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What is a **chromophore** *in this context?*
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Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

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aka *photoa*

Thermal

Ph abla

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two categories

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The laser's wavelength is set so as to be absorbed by **melanin**, which isn't encountered until the energy has passed through the conj/sclera and reached the pigmented epithelium of the CB

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Photo-chemical *aka photoactivation*	**Thermal**	Photo-ablation	Plasma-induced ablation	Photo-disruption *aka plasma-induced disruption*
Very-low-power laser energy causes a photosensitive dye to undergo chemical rxn	Laser energy is absorbed→ transforms into heat→ local thermal damage			
PDT	**Argon, diode**			

No question—proceed when ready

Q

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Photo-chemical	Thermal	**Photo-ablation**	Plasma-induced ablation	Photo-disruption
aka *p*				aka *plasma-* *…tion*

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What sort of laser is used to ablate the corneal tissue?
An **excimer** laser

What is the origin of the word excimer*?*
It is a portmanteau of the term ‘***exci***-ted di-***mer’***

What is the wavelength of light employed?
193 nm

Is 193 nm in the UV range, or the infrared range?
UV

Does light of this wavelength penetrate tissue?
Hardly at all (which makes it perfect for *surface* ablation)

Is this wavelength mutagenic?

…ances) employed during photoablation …ser?

…ust cause even greater heat-mediated …se?
…essentially no energy transfer in the

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What therapy is the classic example of photoablation?
Photoablative keratorefractive surgery (eg, LASIK)

A

Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

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PDT	Argon, diode	**Excimer**		

No question—proceed when ready

Q

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How does plasma-induced ablation alter tissue?
In addition to breaking covalent bonds, the laser 'strips' electrons from molecules (thereby transforming the molecules into ions) and accelerates them. The accelerated electrons fly off and smash into other molecules, in turn ionizing them and accelerating **their** electrons.

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The femtosecond laser

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PDT	Argon, diode	Excimer	**Femtosecond**	

No question—proceed when ready

Q

Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

Photo-

Thermal

Photo-

Plasma-induced

aka

V

p

c

Photo-disruption

aka *plasma-induced disruption*

Like plasma-induced ablation, photodisruption involves the creation of plasma. How do they differ in that regard?

A

Lasers: Pew! Pew!

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Like plasma-induced ablation, photodisruption involves the creation of plasma. How do they differ in that regard?

In plasma-induced ablation, a modest amount of energy is used, resulting in the production of a relatively small amount of plasma. In contrast, photodisruption employs much more energy, resulting in the creation of a great deal more plasma.

Q

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OK, so photodisruption involves substantially more plasma. Why does this justify classifying it as a separate mode of laser-tissue interaction?

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Because the increased plasma creation results in the production of mechanical forces (shock waves; acoustic waves) that propagate well beyond the laser spot, causing tissue to be torn apart remote from the area of laser application

Q

Lasers: Pew! Pew!

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What therapy is the classic example of photodisruption?
YAG capsulotomy

Lasers: Pew! Pew!

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PDT	**Argon, diode**	**Excimer**	**Femtosecond**	**YAG cap**

No question—review slide