Q

Lasers: Pew! Pew!

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

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

A

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Light Amplification by Stimulated Emission of Radiation

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Amount of energy carried away

Planck's constant

Frequency of the light

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What sort of substance can serve as the active medium in a laser?
Lots of different sorts. It can be a gas (eg, argon), a liquid (dye), a solid (eg, Nd:YAG); it can also be a manufactured item (eg, diode)

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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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Are all four substances the active medium (media)?
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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How does all this

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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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What can be done to get more 'bang for the buck' from a laser?
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As an important aside: What other step can be taken to increase the intensity of laser energy?

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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

*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

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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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Fluence = energy/area. (We will soon see that one laser procedure is known for being 'low fluence.')

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Lasers: Pew! Pew!

What is the essence of laser-tissue interaction?

A

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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?

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Tissue-related factors

Laser-related factors

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- *?*
- *?*

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- Composition
- Chromophores

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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)

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Hemoglobin and **melanin**

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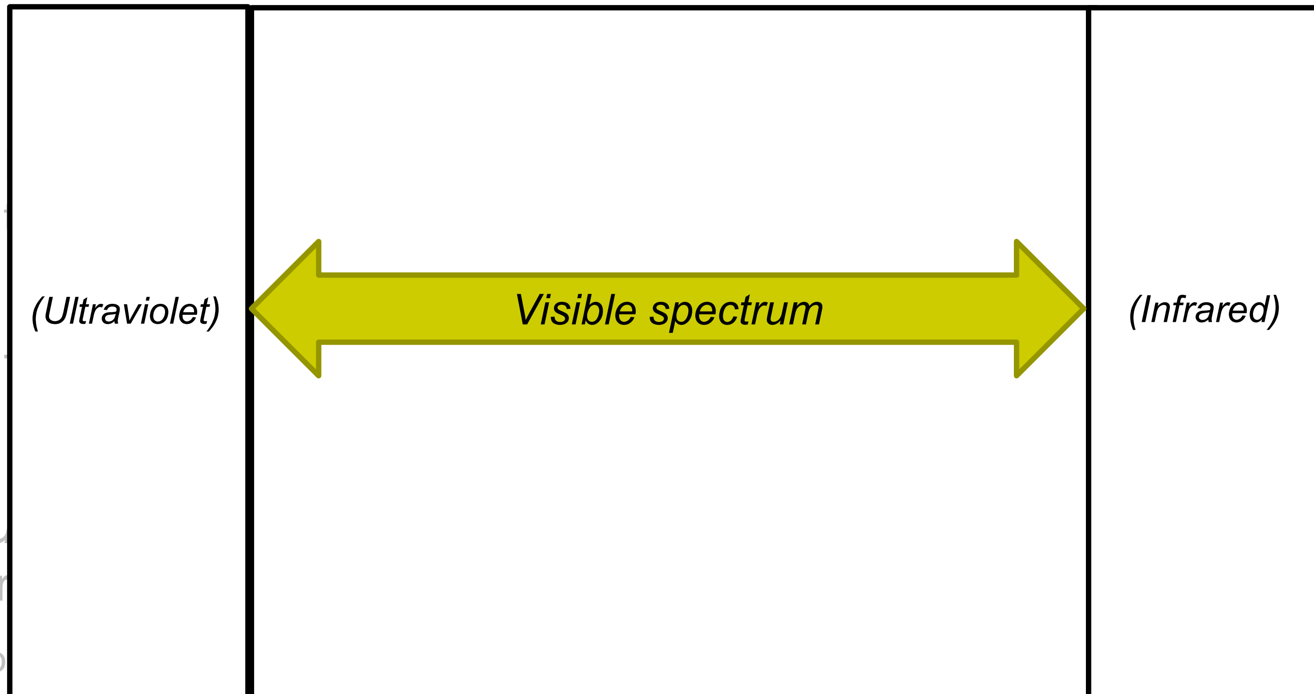
Xanthophyll

(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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Hemoglobin and **melanin**

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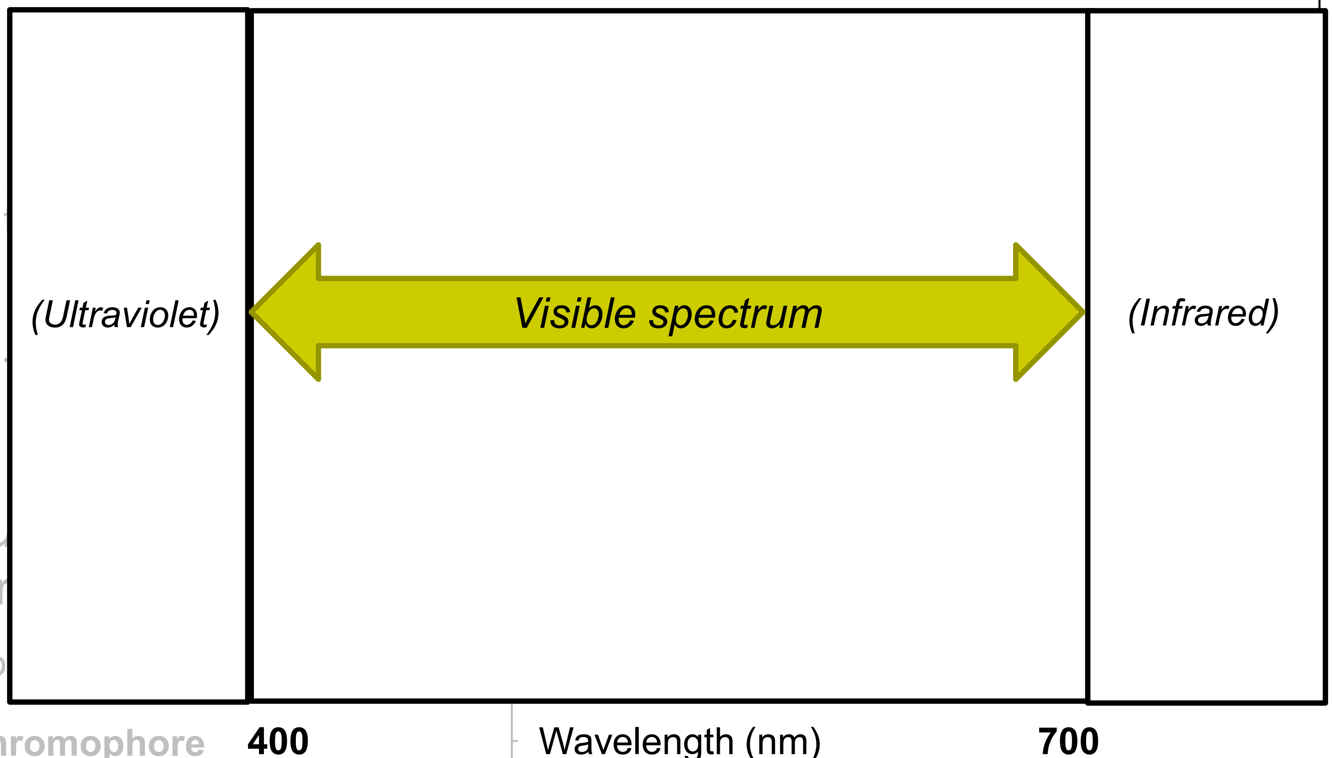

Tissu
factor
Co
Chromophore

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

What two naturally-occurring **chro**
the eye are exploited in ophthalm
Hemoglobin and **melanin**

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

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

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Q

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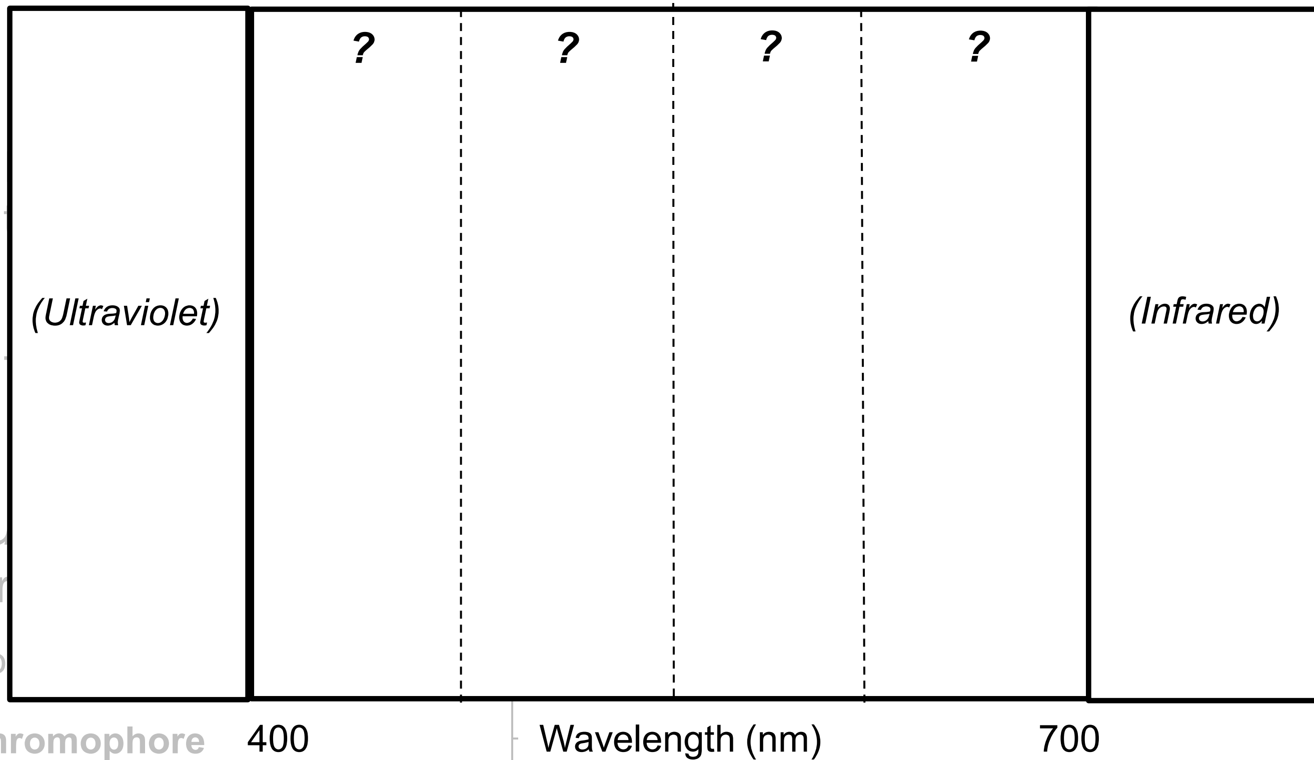

Tissu
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Chromophore

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

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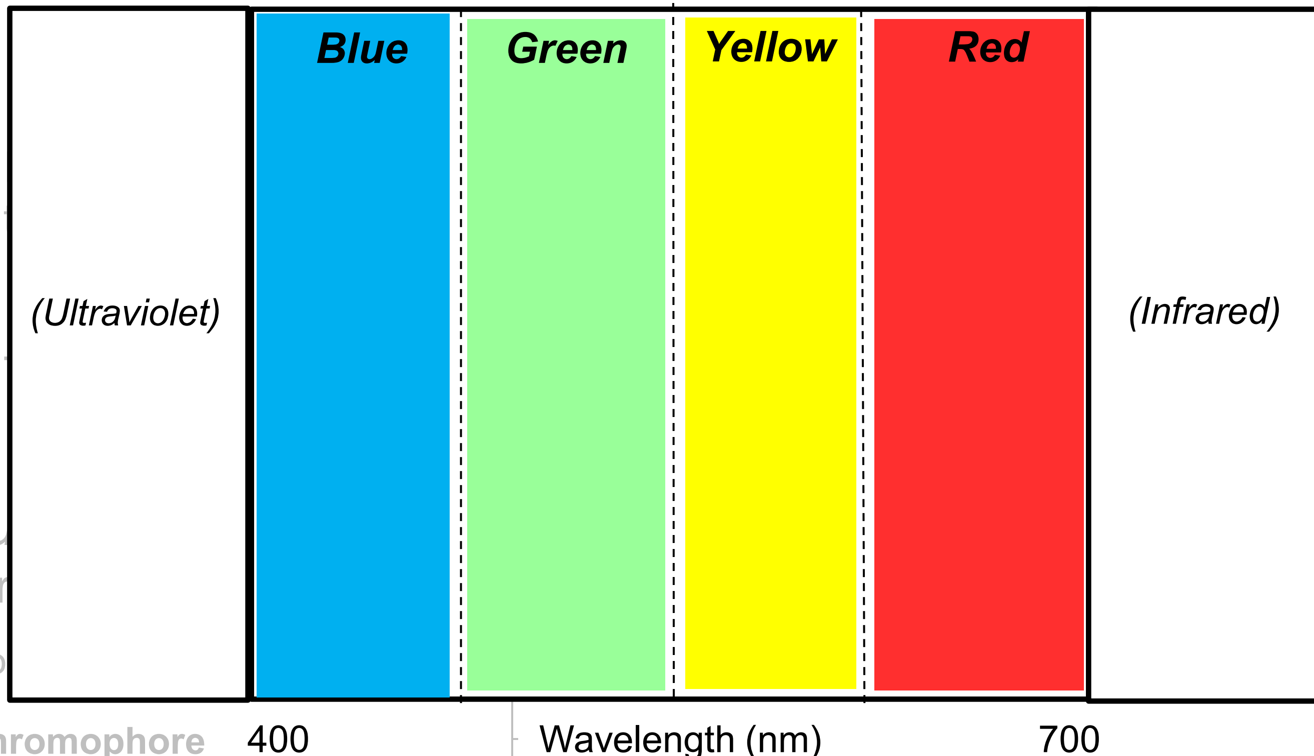
Lasers: Pew! Pew!



Tissu

factor

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Chromophore

What is a **chrom**

A molecule that a

a manner that re

What two naturally-occurring **chro**

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Hemoglobin and **melanin**

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

Blue, **green**, **yellow**, **red**

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

Xanthophyll

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Q

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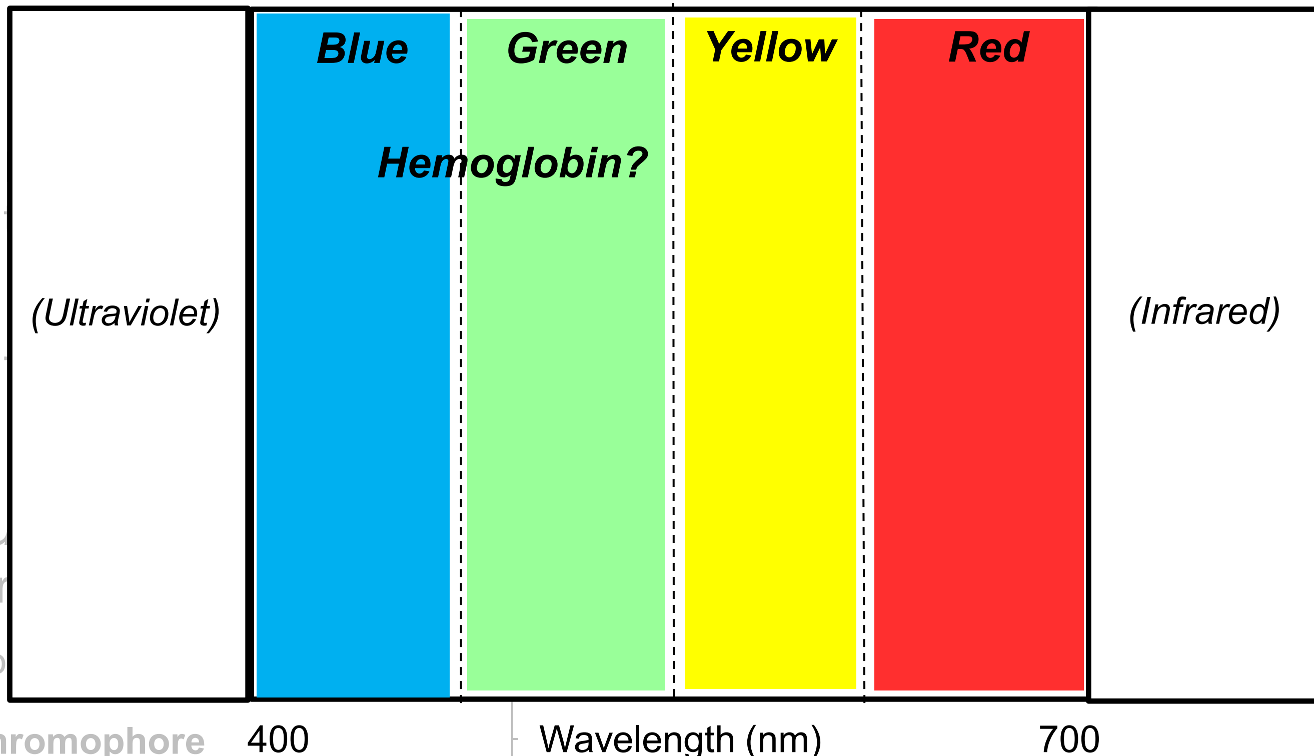

Tissu
factor
Co
Chromophore

What is a ***chrom***
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: ***Hemoglobin****?*

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

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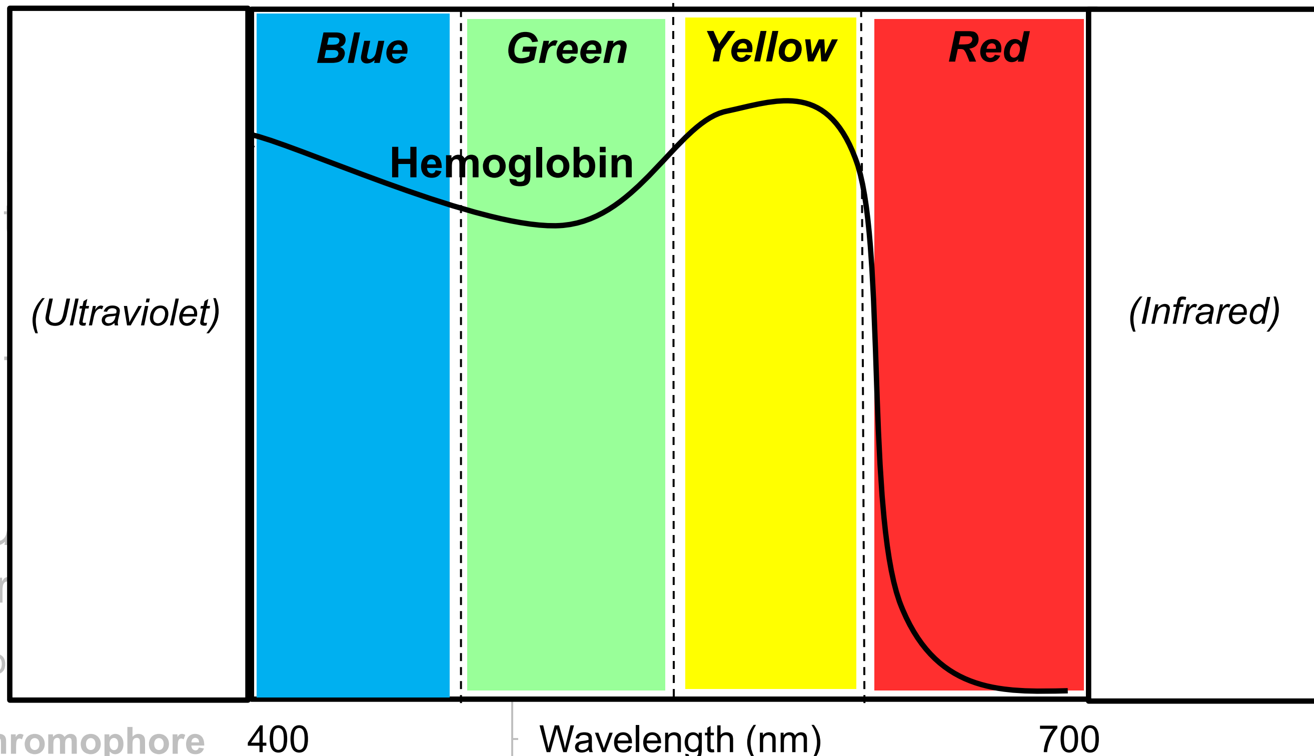
A

Lasers: Pew! Pew!



Tissu

factor

Co

Chromophore

What is a **chrom**

A molecule that a

a manner that re

What two naturally-occurring **chro**

the eye are exploited in ophthalm

Hemoglobin and **melanin**

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

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

Xanthophyll

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Q

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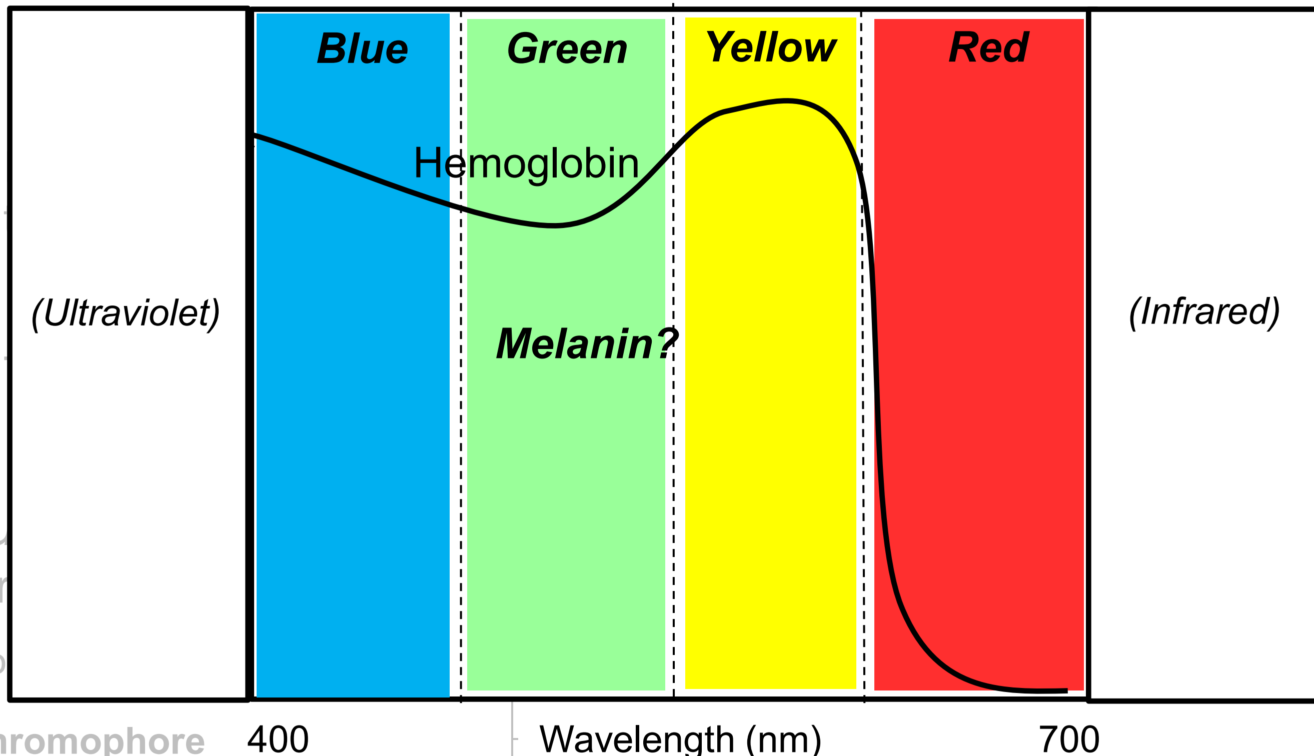

Tissu

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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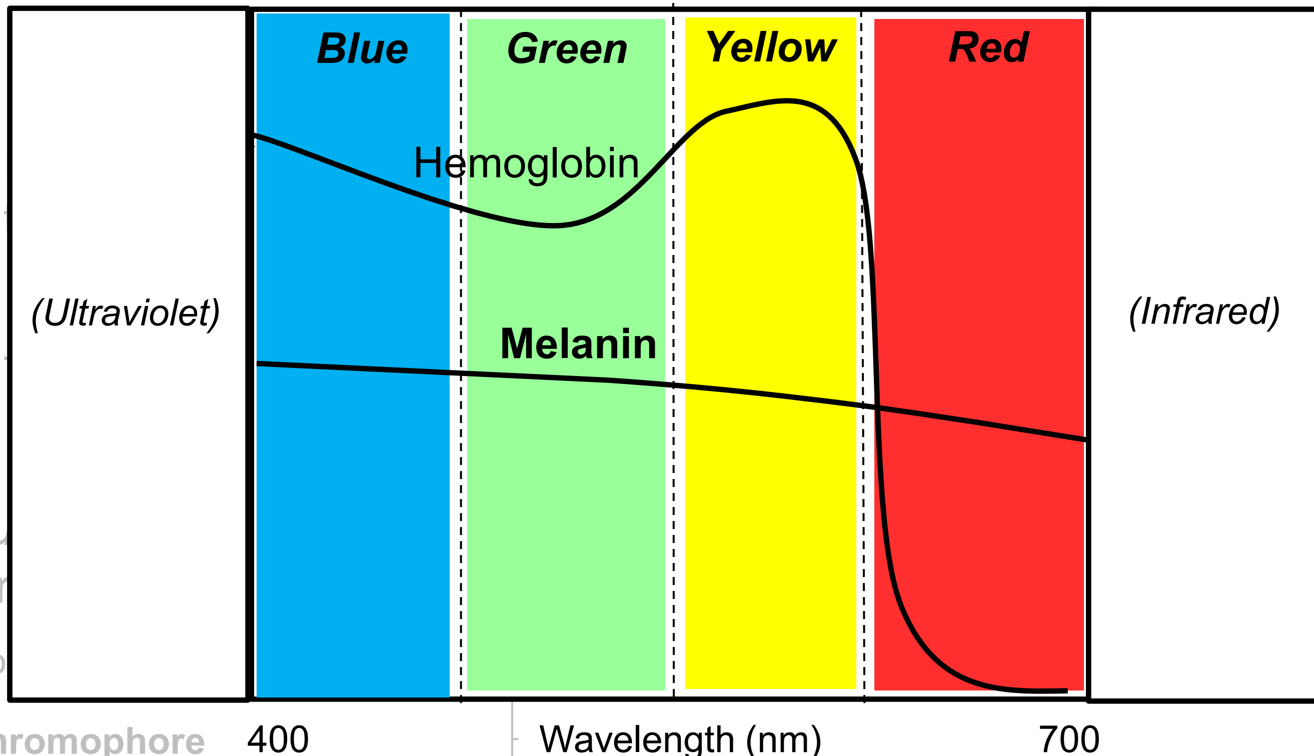

Tissu
factor

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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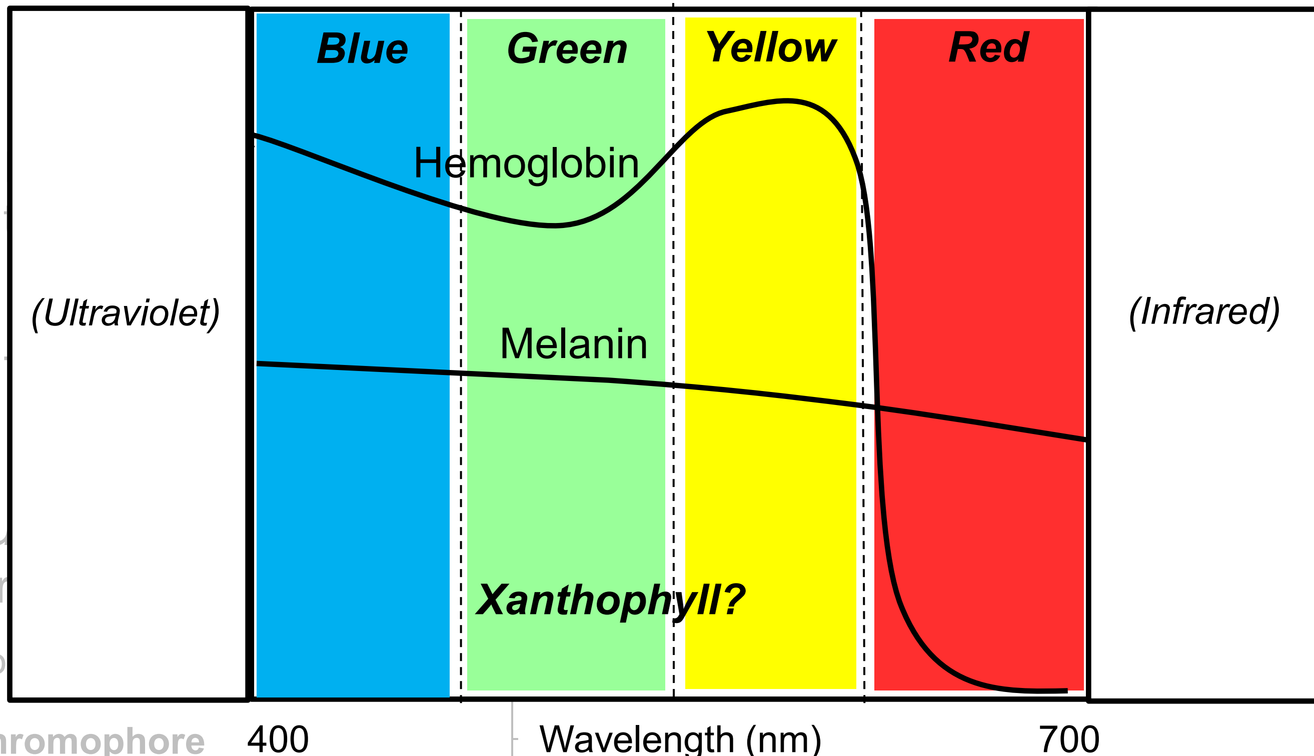

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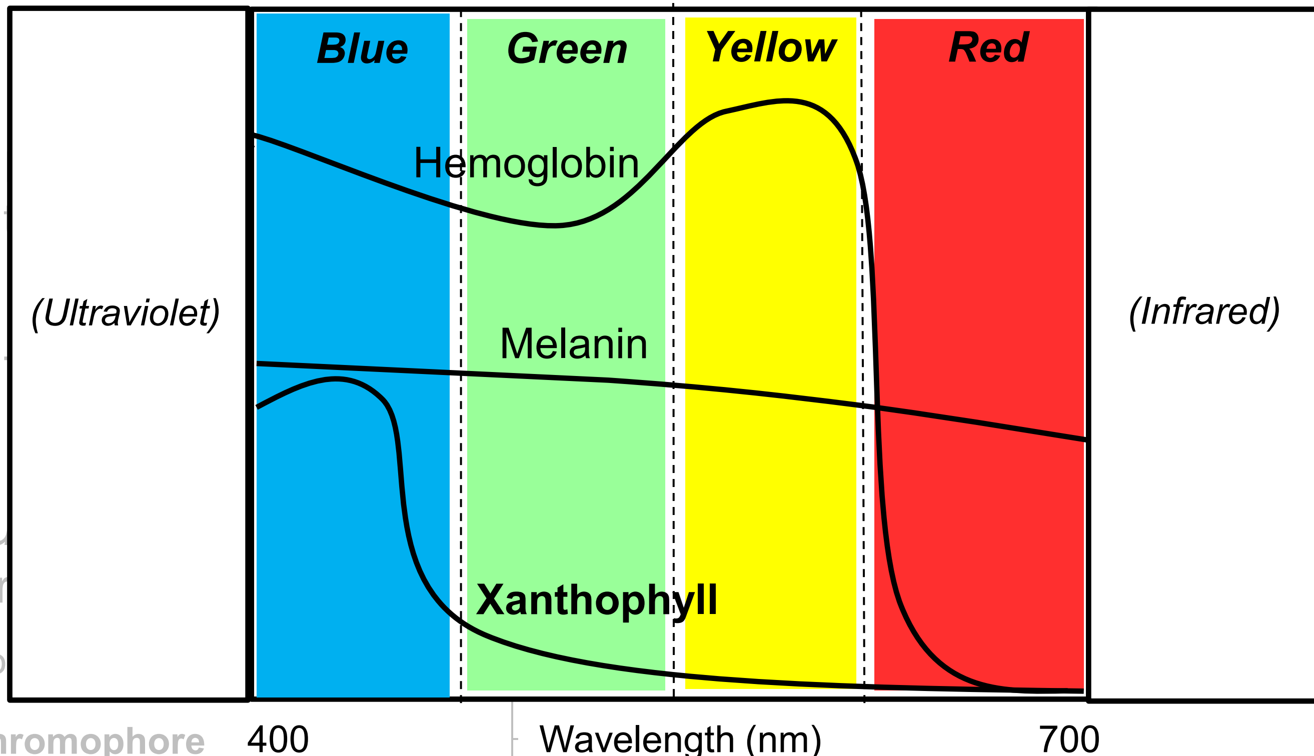

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Which portion of the visible spectrum is well absorbed by: Xanthophyll? **Only blue**

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Xanthophyll

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

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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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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

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

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Irradiance

~~Power density~~

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

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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 **m**^{2}, not cm^2)

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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:

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

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

(usually in cm^2)

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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 cm^2)

Which can be rewritten as:

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

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

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

Note th…

Inde…
(usu…

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

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

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

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

=

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

=

Note th...

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This formulation neatly illustrates how intensity can be increased by:
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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*

Q

Lasers: Pew! Pew!

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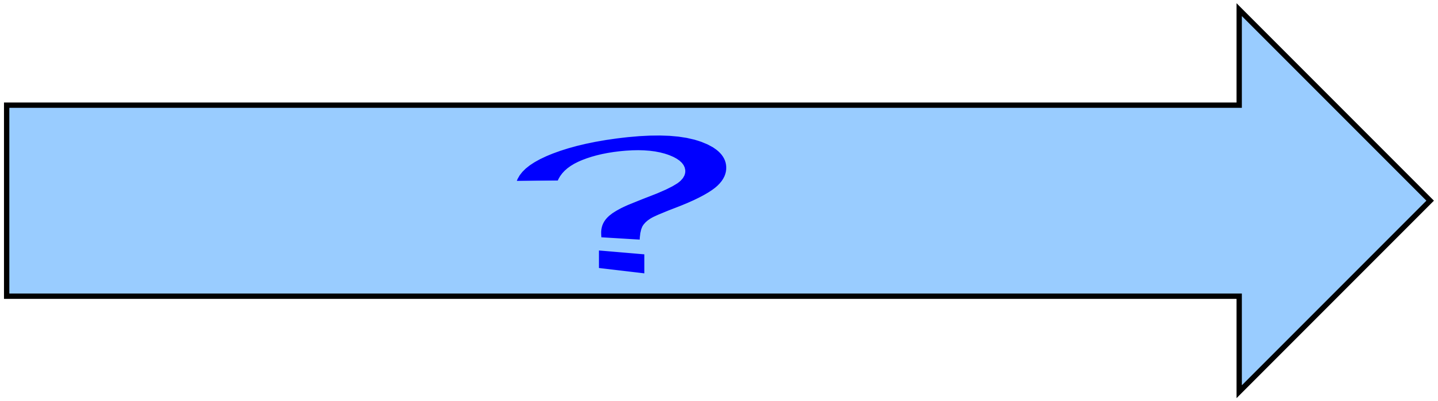
Are these thrown up here rando, or are they in an order of some sort?

Q/A

Lasers: Pew! Pew!

What are the five modes of laser-tissue interaction?

Photo-chemical	Thermal	Photo-ablation	Plasma-induced ablation	Photo-disruption
aka *photoactivation*				aka *plasma-induced disruption*



Are these thrown up here rando, or are they in an order of some sort?
Not rando. Although there is some overlap (especially between *plasma-induced ablation* and *photodisruption*), overall these are listed in order of increasing .

A

Lasers: Pew! Pew!

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

Q/A

Lasers: Pew! Pew!

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

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Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

Photo-chemical aka *photoactivation*	Thermal	Photo-ablation	Plasma-induced ablation	Photo-disruption aka *plasma-induced disruption*

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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1) A photosensitizing dye is injected intravenously, and time sufficient to allow concentration of the dye in the target lesion is allowed to pass
2) The laser is then used to 'light up' the lesion with light of a wavelength that will activate the dye
3)

4)

Q/A

Lasers: Pew! Pew!

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3) The activated dye reacts with [element] to create [three words] which cause local [two words]
4)

Q/A

Lasers: Pew! Pew!

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Q/A

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

A

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4) Platelet activation produces thrombosis of the lesion's vasculature.

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What therapy is the classic example of photochemical laser?
Photodynamic therapy (PDT)

Q

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Q/A

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Prior to the development of intravitreal anti-VEGF therapy, PDT was the tx of choice for choroidal neovascular membranes. While it has been largely supplanted for this indication, it is still employed in the tx of [three words], as well as for some intraocular tumors.

A

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Q

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What is the name of the dye used in PDT?

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What is the name of the dye used in PDT?
Verteporfin

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How much time is allowed to pass?

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How much time is allowed to pass?
10 minutes

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83 seconds

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Lasers: Pew! Pew!

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*

cal laser procedure?

usly, and time sufficient to

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PRP laser

A

Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

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

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In the briefest of manners, describe the PRP procedure.
Several thousand laser burns are placed throughout the retinal periphery

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Q

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What does VEGF *stand for in this context?*
Vascular endothelial growth factor

Q

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Photo-disruption
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Briefly, what steps are involved in a photochemical laser procedure?
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.

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Lasers: Pew! Pew!

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? = Energy/*time*

Note the change!

(The same word goes in each of the three blanks)

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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.

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PDT

No question—proceed when ready

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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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***Tissue*-related factors**

Composition

Chromophore

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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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Q

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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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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	Laser energy is absorbed→ transforms into heat→ local thermal damage			
PDT	**Argon, diode**			

No question—proceed when ready

Q

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193 nm

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

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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

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

...less *thermal damage?*
...ecular motion (which is what heat is)

...on alter tissue?
...carbon-nitrogen bonds

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

Q

Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

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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	Laser energy disrupts covalent bonds		
PDT	Argon, diode	**Excimer**		

No question—proceed when ready

Q

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The five modes of laser-tissue interaction:

Photo-chemical	Thermal	Photo-ablation	**Plasma-induced ablation**	Photo-disruption

Are the laser intensities (power densities; irradiances) employed during plasma-induced ablation greater than those employed during 'regular' photoablation?

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Yes (in fact, the durations are significantly shorter than are those of photoablation)

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.

A

Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

Photo-chemical aka ... | Thermal | Photo-ablation | **Plasma-induced ablation** | Photo-disruption aka plasma ... on

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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. This *cascade ionization process* results in the transformation of tissue into plasma (a gas composed of ions and free electrons). In this manner, the tissue sort of 'goes away.'

Q

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What therapy is the classic example of plasma-induced ablation?
The femtosecond laser

Lasers: Pew! Pew!

The five modes of laser-tissue interaction:

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	Laser energy disrupts covalent bonds	Laser energy produces minute amount of plasma, causing local vaporization of tissue	
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

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!

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?

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

The five modes of laser-tissue interaction:

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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