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Undergraduate Research Award
in Physiology
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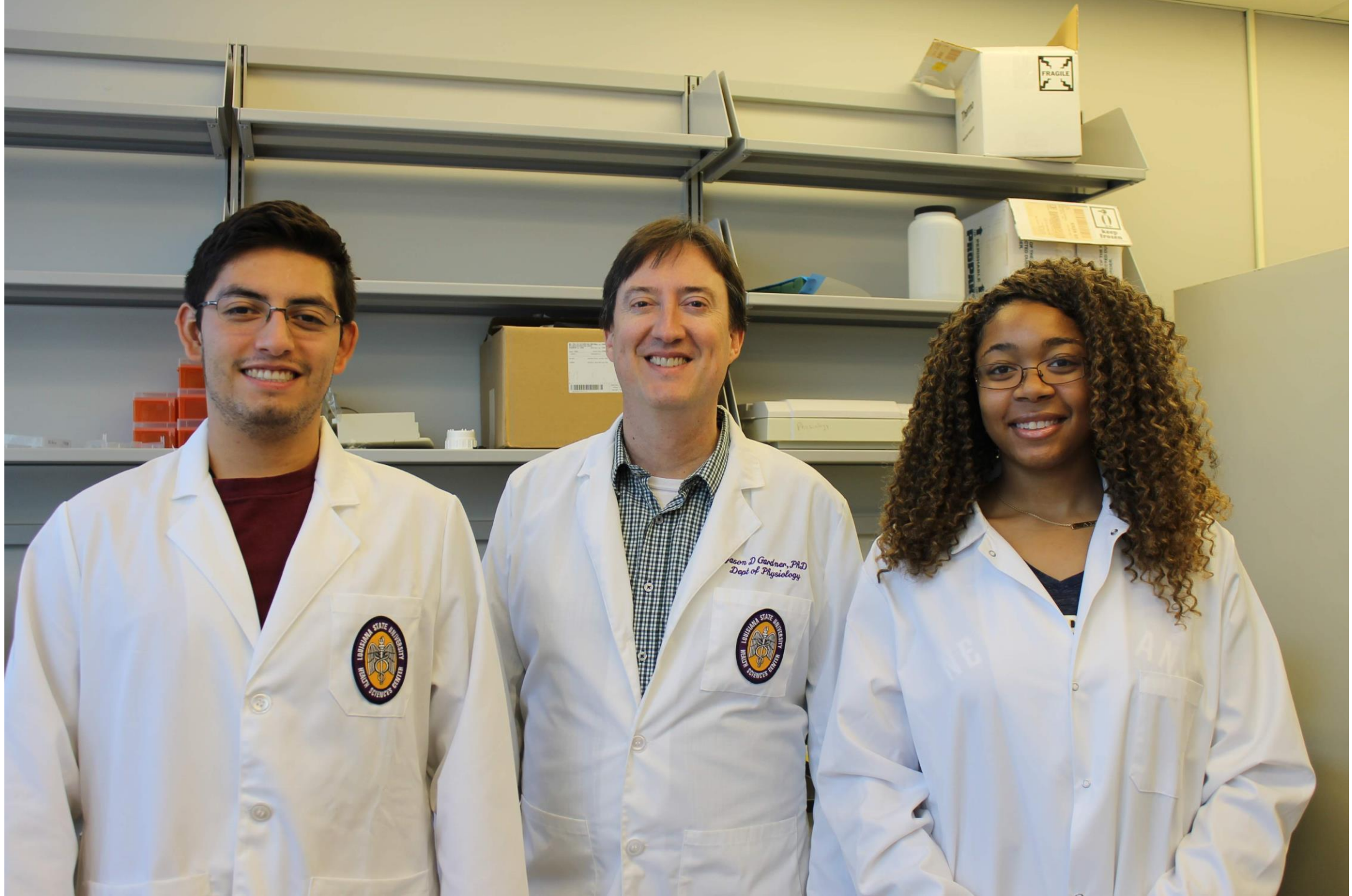
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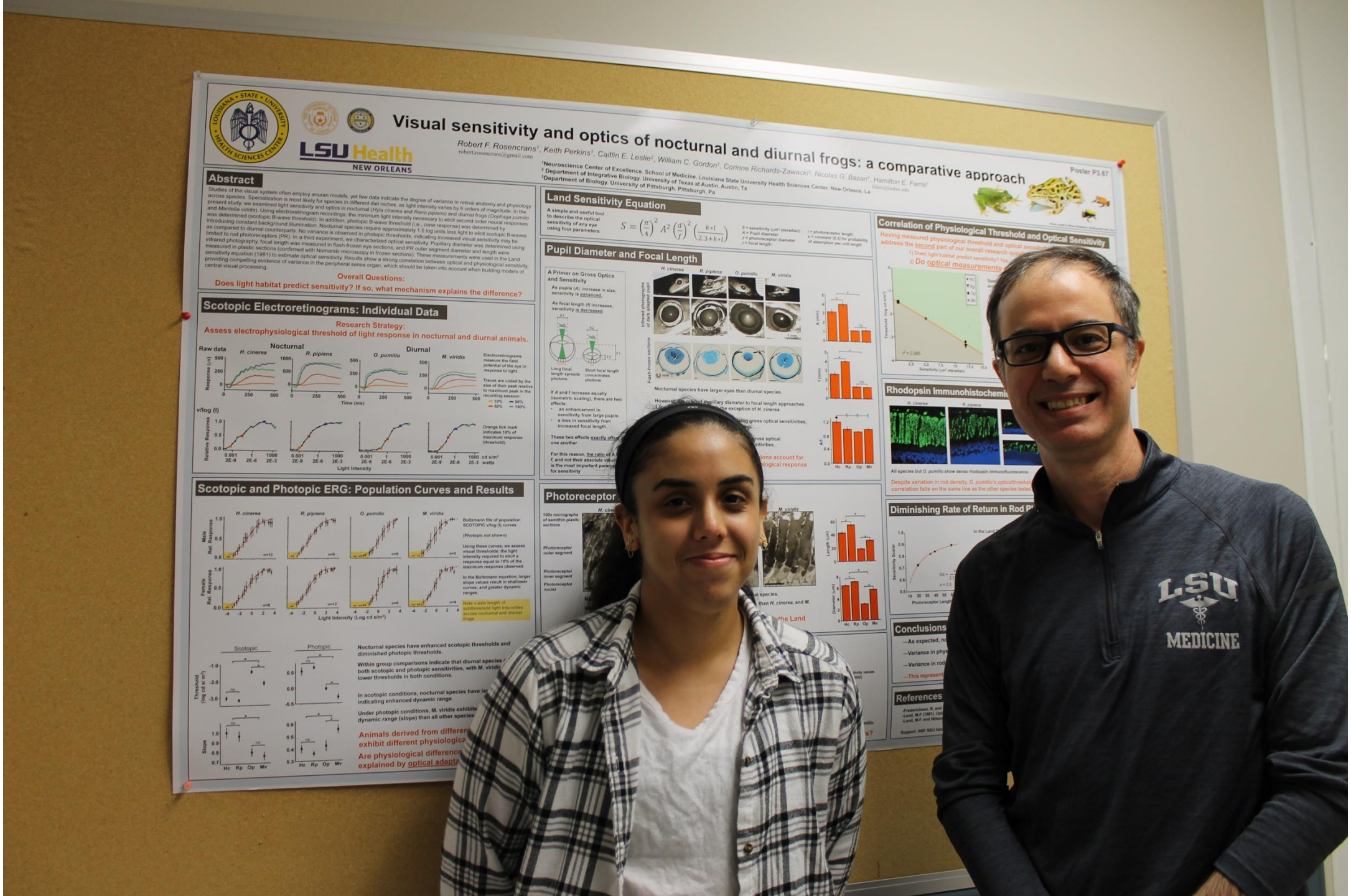
Visual sensitivity and optics of nocturnal and diurnal frogs: a comparative approach
Poster P3.67
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Abstract
Studies of the visual system often employ anuran models, yet few data indicate the degree of variance in retinal anatomy and physiology across species. Specialization is most likely for species in different diel niches, as light intensity varies by 6 orders of magnitude. In the present study, we examined light sensitivity and optics in nocturnal (Hyla cinerea and Rana pipiens) and diurnal frogs (Osophaga pumilio and Mantella viridis). Using electroretinogram recordings, the minimum light intensity necessary to elicit second order neural responses was determined (scotopic B-wave threshold). In addition, photopic B-wave threshold (i.e., cone response) was determined by introducing constant background illumination. Nocturnal species require approximately 1.5 log units less light to elicit scotopic B-waves as compared to diurnal counterparts. No variance is observed in photopic thresholds, indicating increased visual sensitivity may be limited to rod photoreceptors (PR). In a third experiment, we characterized optical sensitivity. Pupillary diameter was determined using infrared photography, focal length was measured in flash-frozen eye sections, and PR outer segment diameter and length were measured in plastic sections (confirmed with Nomarski microscopy in frozen sections). These measurements were used in the Land sensitivity equation (1981) to estimate optical sensitivity. Results show a strong correlation between optical and physiological sensitivity, providing compelling evidence of variance in the peripheral sense organ, which should be taken into account when building models of central visual processing.
Overall Questions:
Does light habitat predict sensitivity? If so, what mechanism explains the difference?
Scotopic Electroretinograms: Individual Data
Research Strategy:
Assess electrophysiological threshold of light response in nocturnal and diurnal animals.
Raw data
Nocturnal
Diurnal
H. cinerea
R. pipiens
O. pumilio
M. viridis
Response (uV)
Time (ms)
Electroretinograms measure the field potential of the eye in response to light.
Traces are coded by the size of their peak relative to maximum peak in the recording session:
10%
50%
90%
100%
v/log (I)
Relative Response
Orange tick mark indicates 10% of maximum response (threshold).
Light Intensity
cd s/m²
watts
Scotopic and Photopic ERG: Population Curves and Results
Male Rel. Response
Female Rel. Response
Boltzmann fits of population SCOTOPIC v/log (I) curves
(Photopic not shown)
Using these curves, we assess visual thresholds: the light intensity required to elicit a response equal to 10% of the maximum response observed.
In the Boltzmann equation, larger slope values result in shallower curves, and greater dynamic ranges.
Note x-axis length of subthreshold light intensities across nocturnal and diurnal frogs
Light Intensity (Log cd s/m²)
Scotopic
Photopic
Threshold (log cd s/ m²)
Slope
Hc Rp Op Mv
Nocturnal species have enhanced scotopic thresholds and diminished photopic thresholds.
Within group comparisons indicate that diurnal species
both scotopic and photopic sensitivities, with M. viridis
lower thresholds in both conditions.
In scotopic conditions, nocturnal species have la
indicating enhanced dynamic range.
Under photopic conditions, M. viridis exhibits
dynamic range (slope) than all other species
Animals derived from differen
exhibit different physiologica
Are physiological differenc
explained by optical adapta
Land Sensitivity Equation
A simple and useful tool to describe the optical sensitivity of any eye using four parameters
$S = \left(\frac{\pi}{4}\right)^2 A^2 \left(\frac{d}{f}\right)^2 \left(\frac{k+l}{2.3+k+l}\right)$
S = sensitivity (cm² steradian)
A = Pupil diameter
d = photoreceptor diameter
f = focal length
l = photoreceptor length
k = constant (0.3) for probability of absorption per unit length
Pupil Diameter and Focal Length
A Primer on Gross Optics and Sensitivity
As pupils (A) increase in size, sensitivity is enhanced.
As focal length (f) increases, sensitivity is decreased.
Long focal length spreads photons
Short focal length concentrates photons
If A and f increase equally (isometric scaling), there are two effects:
an enhancement in sensitivity from large pupils
a loss in sensitivity from increased focal length.
These two effects exactly offset one another
For this reason, the ratio of A and f, and not their absolute values, is the most important parameter for sensitivity
Infrared photographs of dark adapted pupil
Flash-frozen sections
Nocturnal species have larger eyes than diurnal species.
Photoreceptor
100x micrographs of semithin plastic sections
Photoreceptor outer segment
Photoreceptor inner segment
Photoreceptor nuclei
Correlation of Physiological Threshold and Optical Sensitivity
Having measured physiological threshold and optical sensitivity
address the second part of our overall research
1) Does light habitat predict sensitivity? Yes
2) Do optical measurements
Threshold (log cd s/m²)
Sensitivity (cm² steradian)
Rhodopsin Immunohistochemi
All species but O. pumilio show dense rhodopsin immunofluorescence.
Despite variation in rod density, O. pumilio's optics/thresh
correlation falls on the same line as the other species teste
Diminishing Rate of Return in Rod P
Sensitivity Scalar
Photoreceptor Length
Conclusions
As expected, no
Variance in phys
Variance in rod
This represent
References
Support: NSF REU
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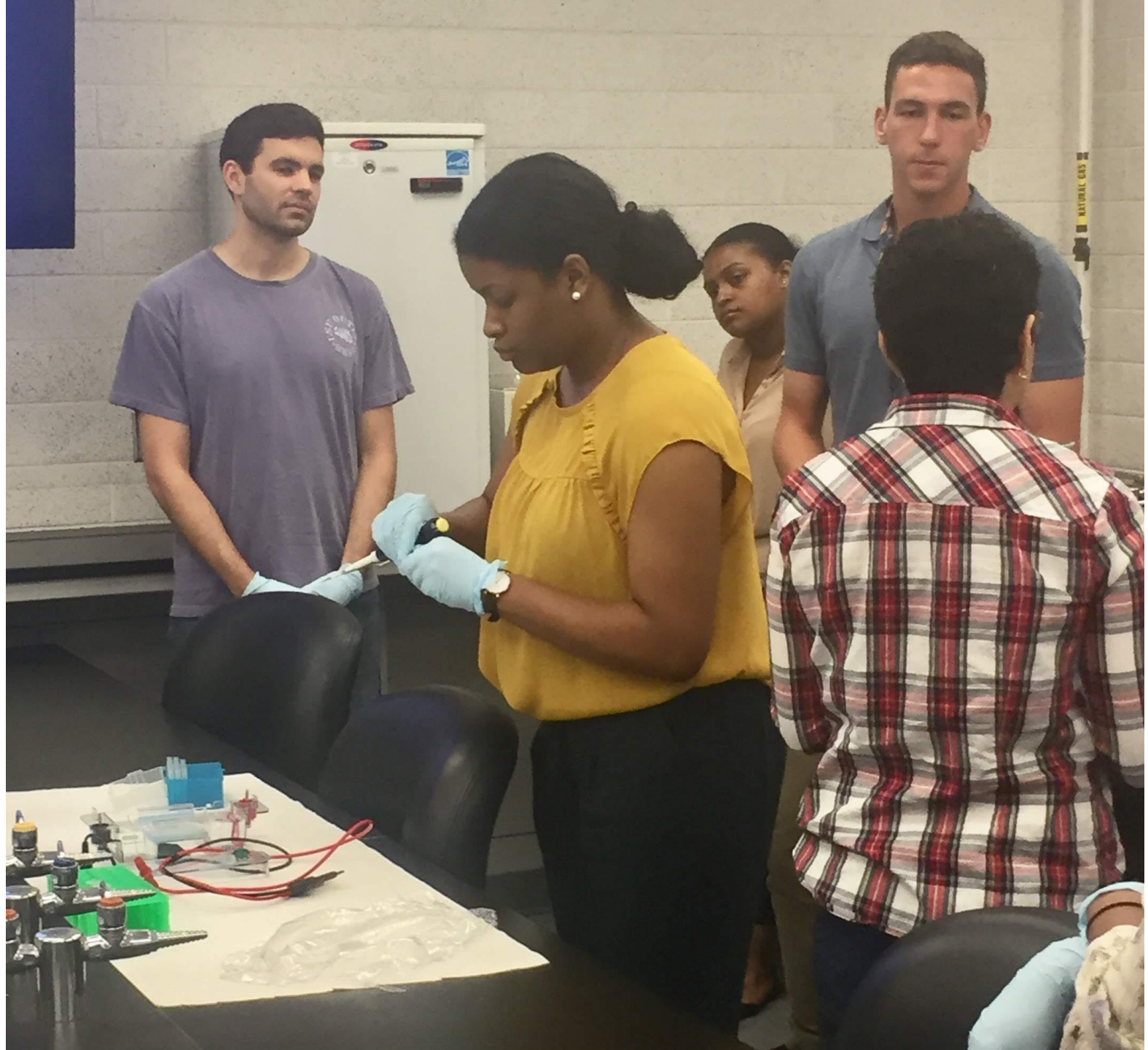


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