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Old windows, new light

Physiological biomarkers in the long wavelength near infrared region

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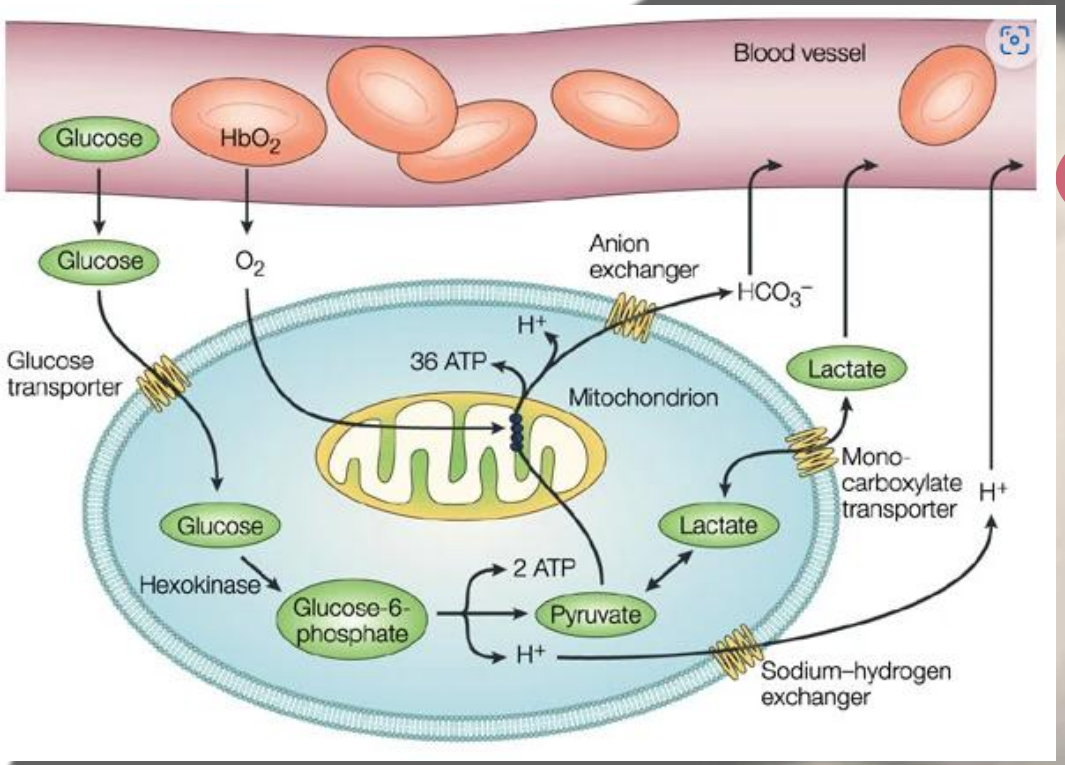
Taighde Éireann Research Ireland
Rialtas na hÉireann Government of Ireland
Tionscadal Éireann Project Ireland 2040
Ireland's European Structural and Investment Funds Programmes 2014-2020
Co-funded by the Irish Government and the European Union
European Union
European Structural and Investment Funds

Hypoxia as a problem in clinic – fetal and neonatal



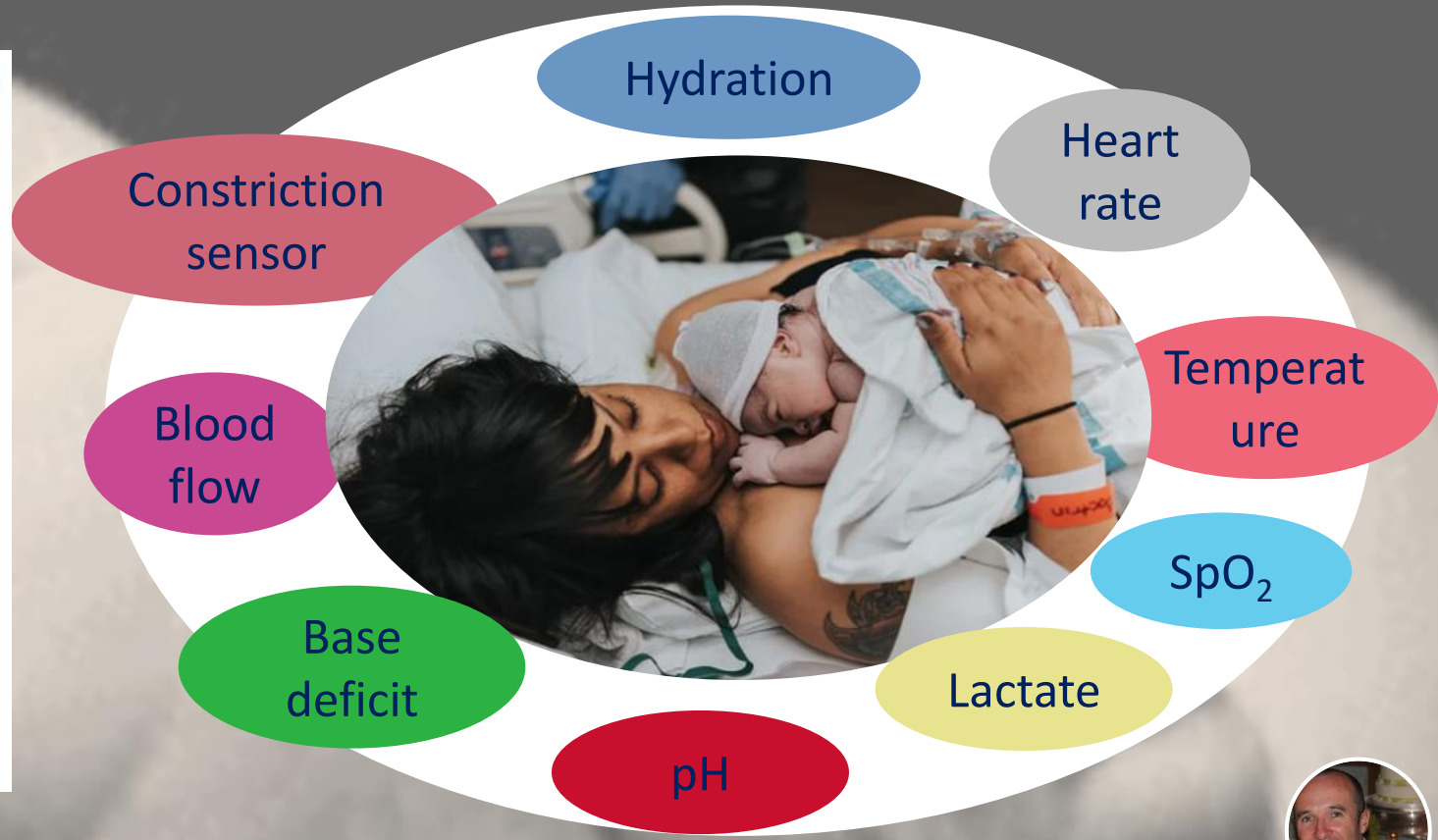
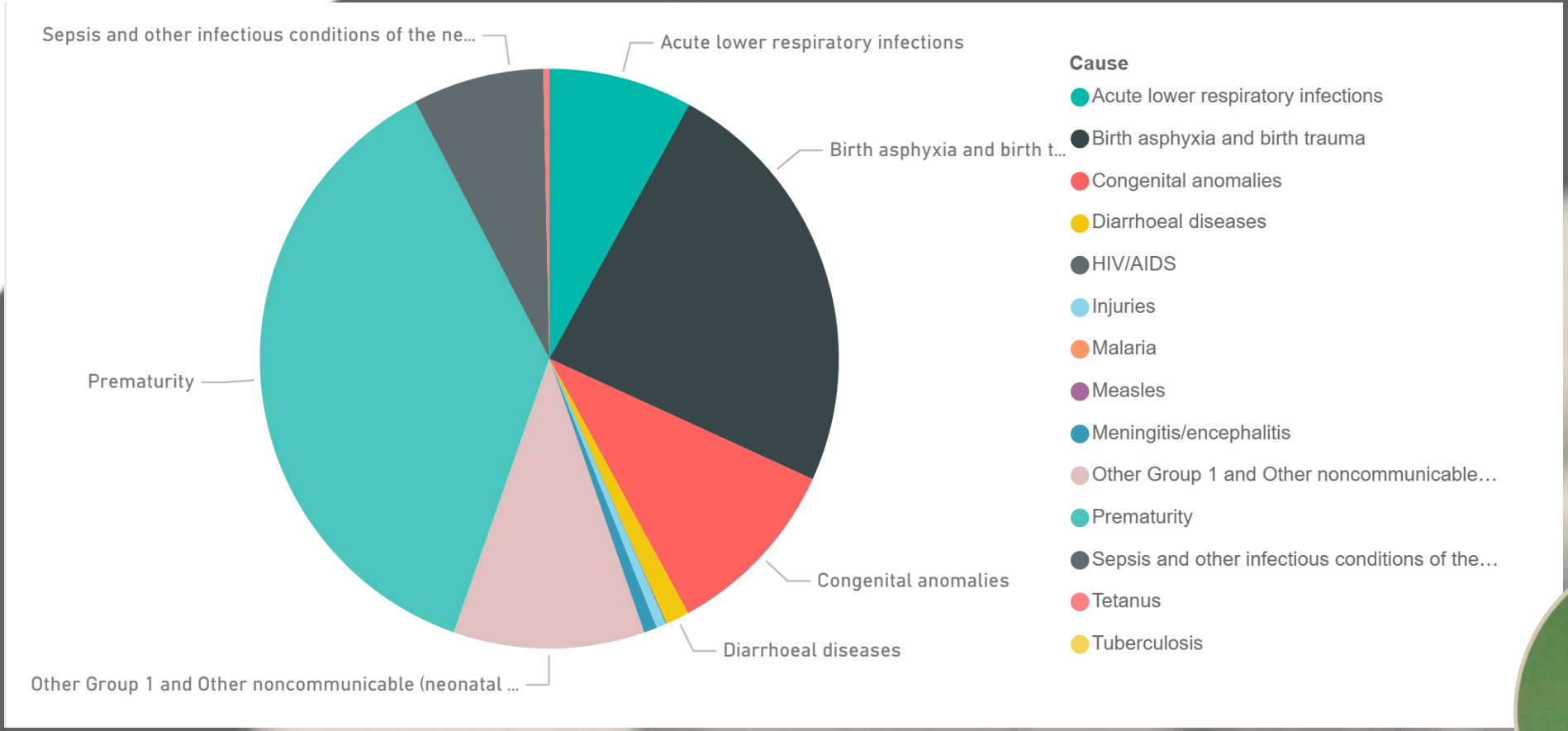


Photo by - www.birthbeco mesher.com from https://www.babylist.com/hello-baby/what-to-expect-at-the-hospital

S. Krishnamoorthy, et al., "Spectral feature exploration for lactate sensing using long wavelength near infrared spectroscopy lactate sensing for non-invasive continuous hypoxia assessment in partum fetus", Proc. SPIE 12628, Diffuse Optical Spectroscopy and Imaging IX, 126280C (28 February 2024)

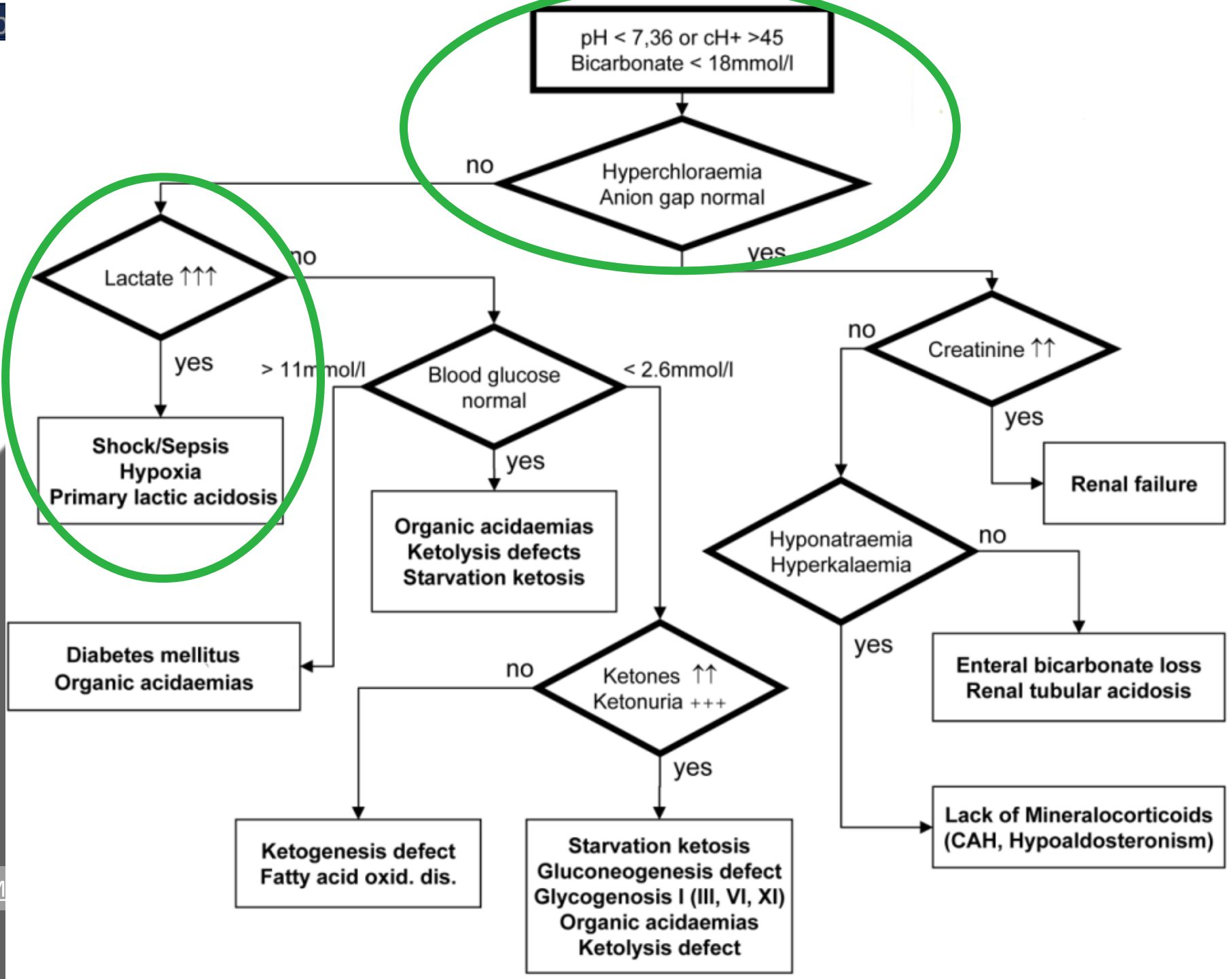
Continuous, chemical-free hypoxia monitoring in early life



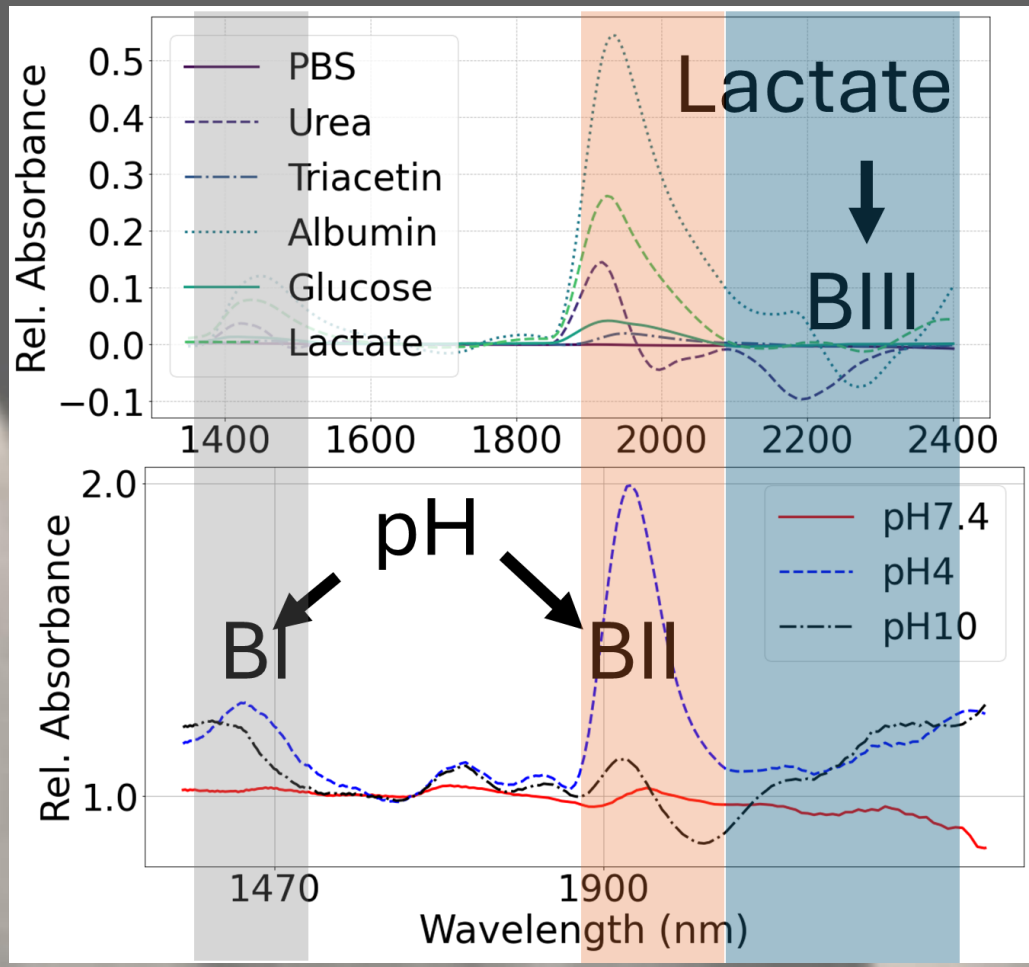
SDG Target 3.2: End preventable deaths of newborns and children under 5 years of age

Number of neonatal deaths - by cause (Accessed 19th Sep, 2025)

Clinics – pH in diagnosis

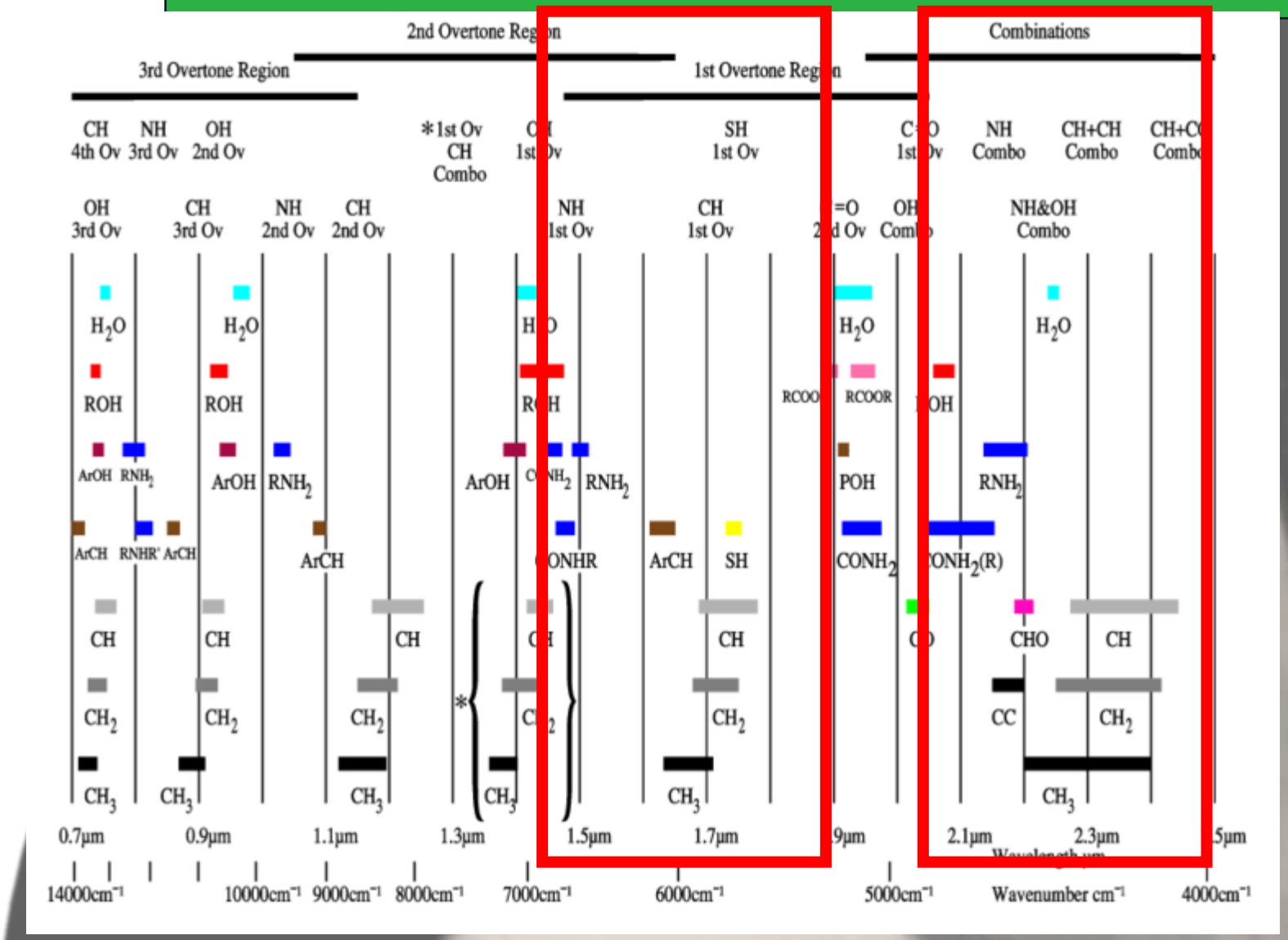


Biomarkers in LWNIR



S. Krishnamoorthy (Unpublished)

Biomarkers in LWNIR



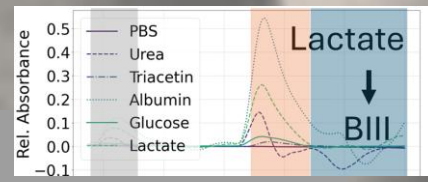
Albumin Creatin ratio

Glucose

Lactate

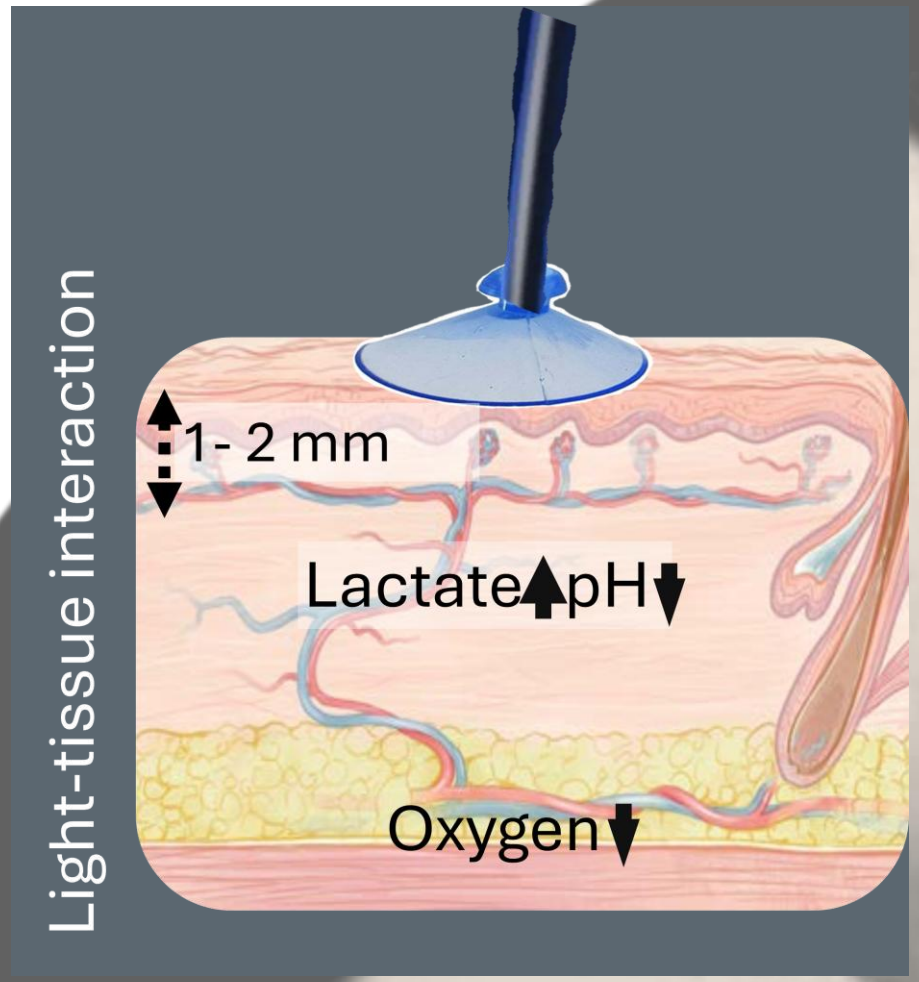
Urea

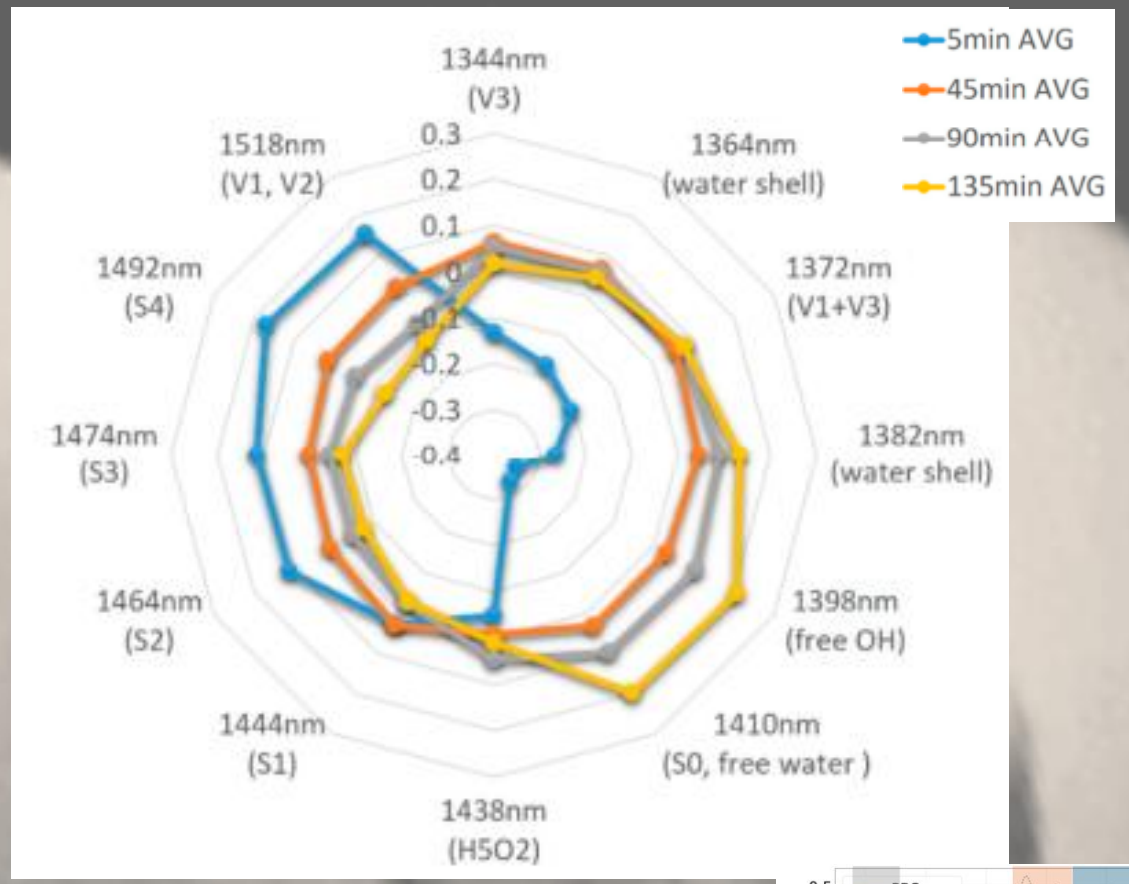
Vibration bands in long wavelength near-infrared regions

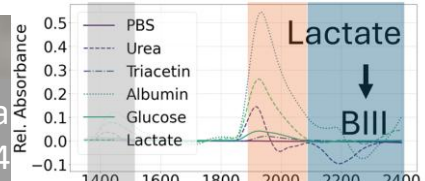


Harris, Philip & Altaner, Clemens. (2013). Workshop on commercial application of IR spectroscopies to solid wood..

Going non-invasive and going spectroscopic

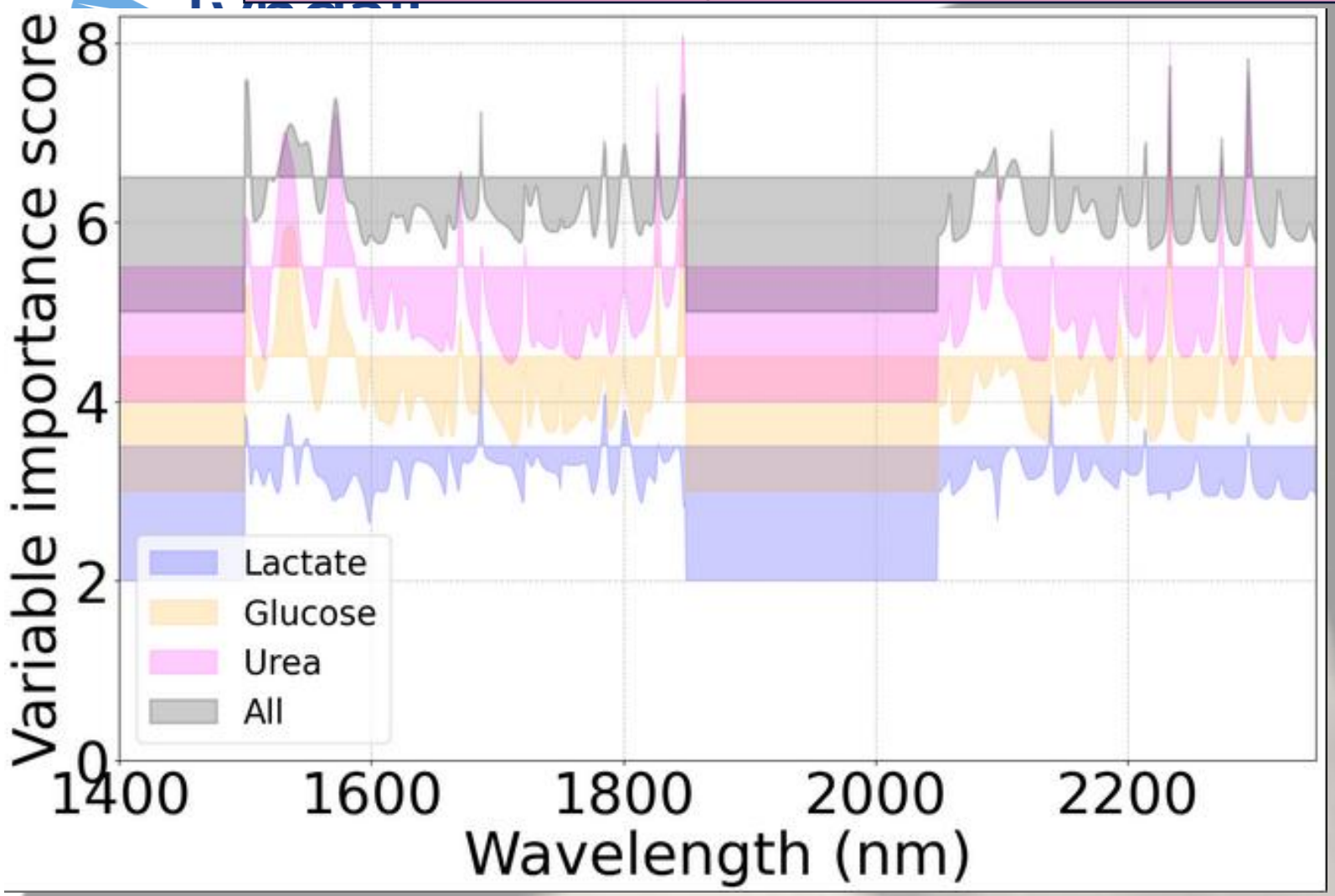


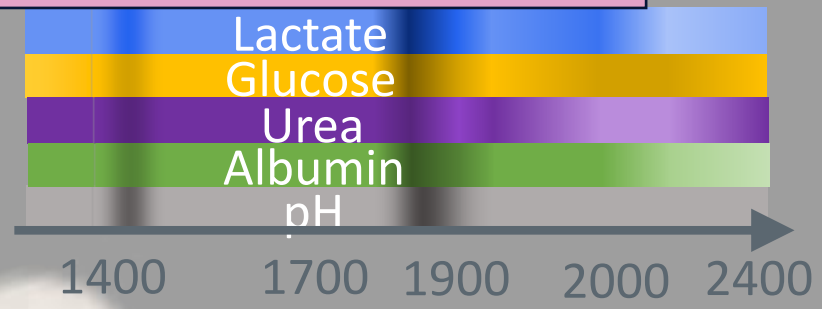




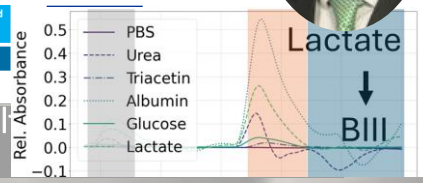
S. Krishnamoorthy, et al., "Beyond Oxygen In-vivo Long-wavelength Near Infra-red Spectroscopy for Hypoxia Assessment," in ECBO 2021, pa
Muncan J, Tsenkova R. Aquaphotomics—From Innovative Knowledge to Integrative Platform in Science and Technology. Molecules. 2019; 24

Multiple biomarker assessment phantoms





Biomarker	R2	Variables
Lactate	0.9859	10
Urea	0.7290	10
Glucose	0.6190	10
All	0.7440	9



S. Krishnamoorthy, W. Messina, C. Kiely, N. Rossberg, A. Visentin, R. Burke, S. Andersson-Engels, “Point-of-care, continuous assessment of mul
long wavelength near infrared spectroscopy for dialysis”, ECBO Munich, Germany (2025)

Lactate assessment in complex systems

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Lactate
pH

1400 1700 1900 2000 2400

Lactate
Glucose
Urea
Albumin
pH

1400 1700 1900 2000 2400

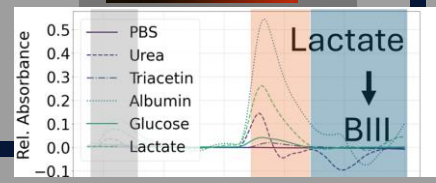
Water
Tissue
Lactate
Glucose
Urea

1400 1700 1900 2000 2400

In PBS

With Interferences`

In serum



Lactate assessment in complex systems

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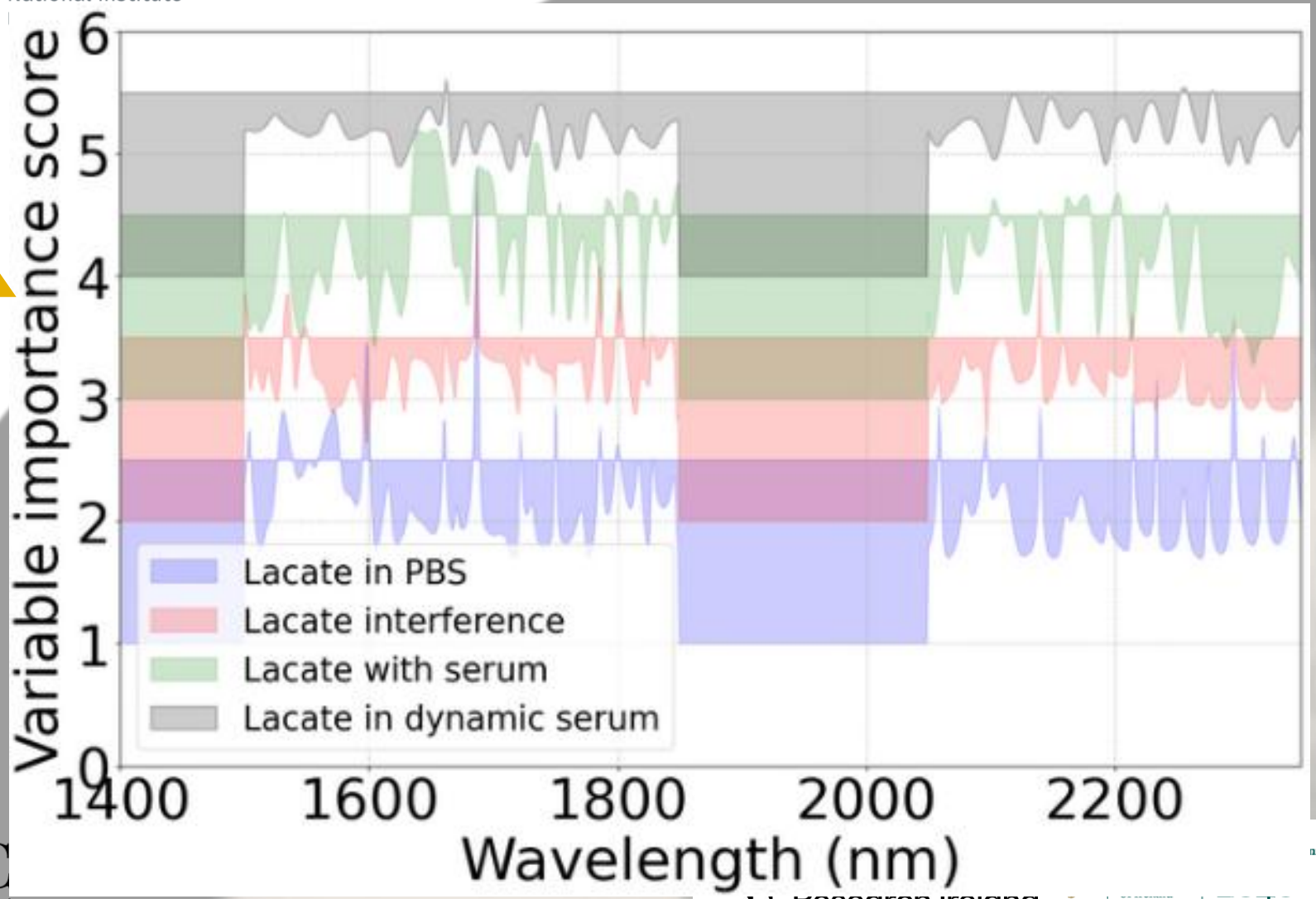
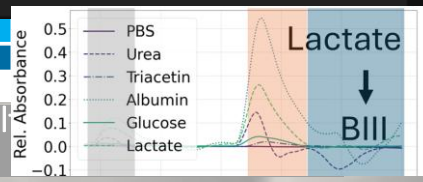
Complexity



Medium	R2	Variables
PBS	0.918627	10
Interference	0.985902	10
Serum	0.982666	10
Dynamic Serum	0.765224	8



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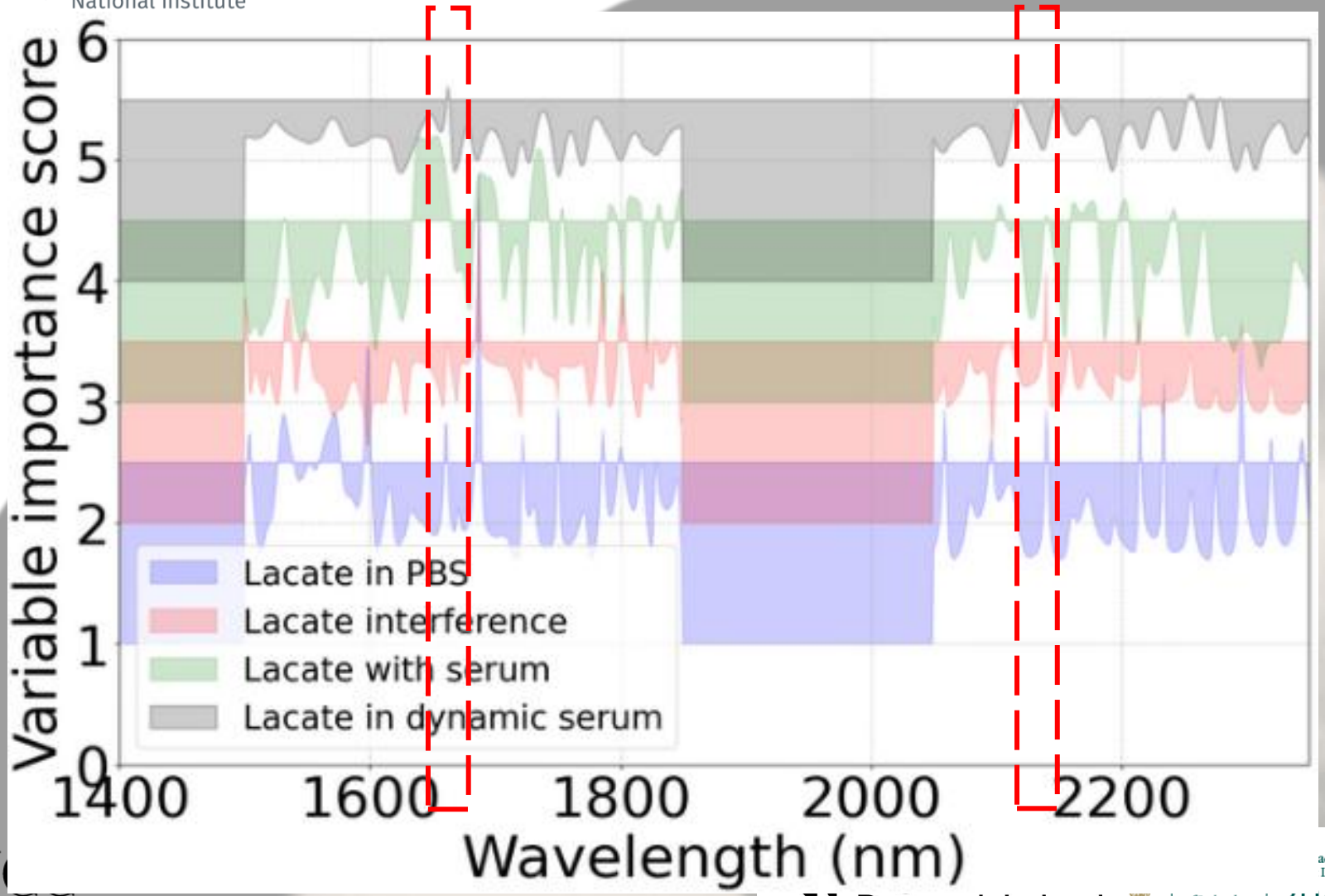
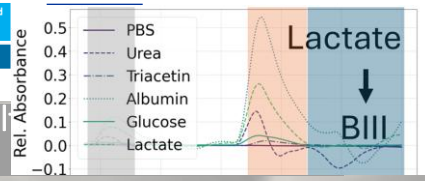


Increasing complexity – loss in sharpness and quality of bands



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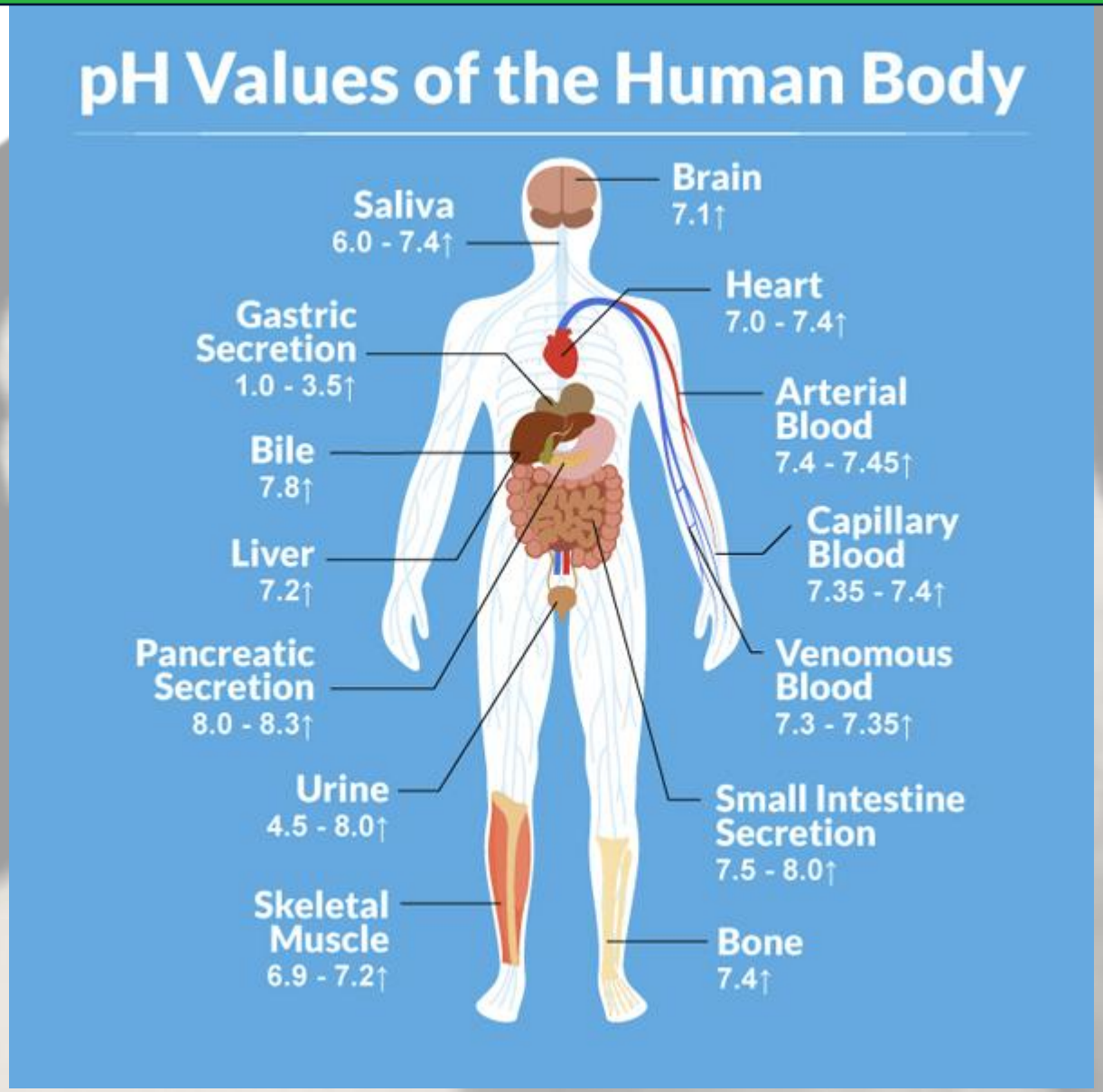
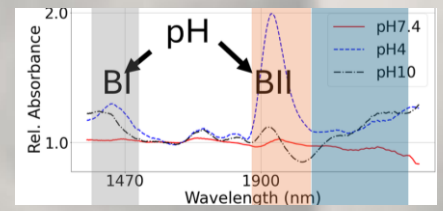
long wavelength near infrared spectroscopy for dialysis", ECBO Munich, Germany (2025)

Current technologies and challenges – physiology

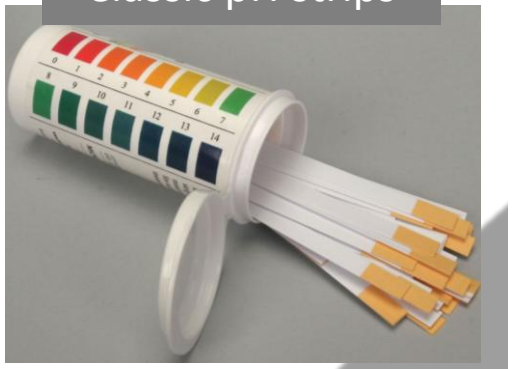




NSD610-010.02-IMD-Metabolic-Acidosis.pdf

Going non-invasive and going spectroscopic – invasive, sample access

Classic pH strips



Calorimetric and ohmic

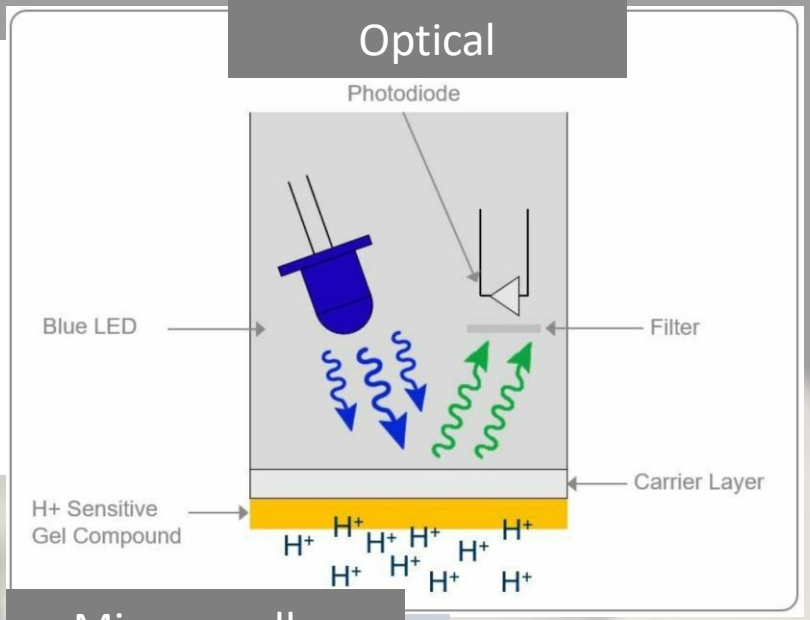
pH Meter Examples

pH 1120X (Portable pH Meter) (Mettler Toledo)

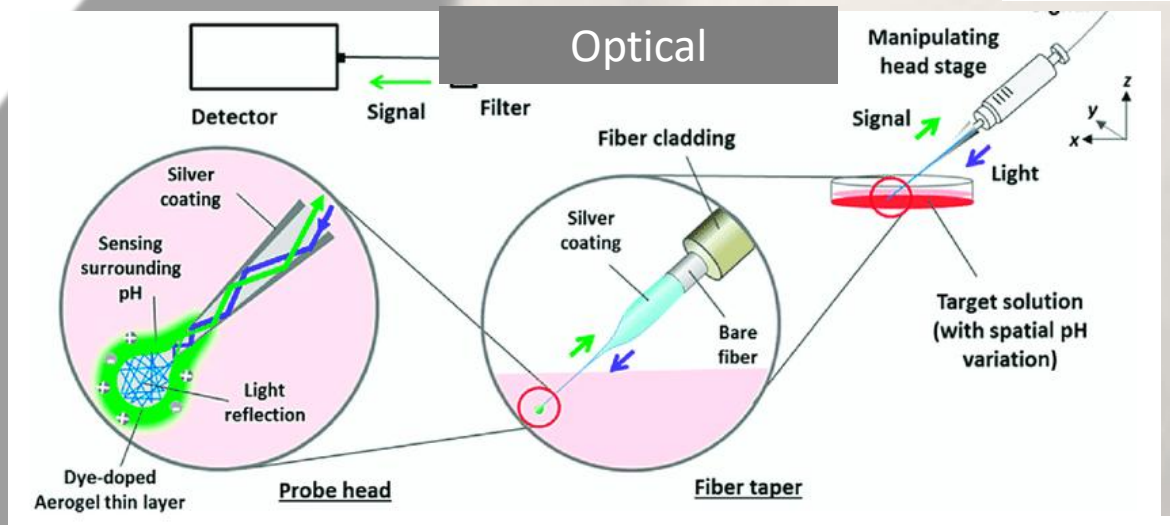
LAQUAtwin pH Meter PH-11 (2 point)

Gastroesophageal impedance pH meter (BLU RUNNER)

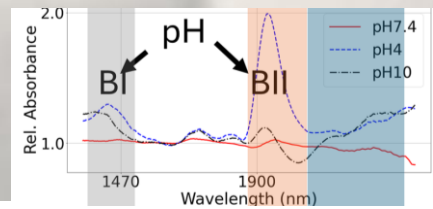
Optical



Optical



Microneedles



Optical Sensing and Imaging of pH Values: Spectroscopies, Materials, and Applications Andreas Steinegger, Otto S. Wolfbeis, and Sergey M. Borisov Chemical Reviews 2020 120 (22), 12357-12489
pH Meter: Principle, Parts, Procedure, Types, Uses, Examples , Glass Membrane Versus Optical pH Sensors | Process Analytics
Berneschi, S. et. al., (2020). Optical Fibre Micro/Nano Tips as Fluorescence-Based Sensors and Interrogation Probes. Optics. 1. 213-242.
F. Rahman et. al, (2025), Microneedle-based electrochemical sensors for real-time pH and sodium monitoring in physiological environments, Sensing and Bio-Sensing Research, Vol. 48, 100777.,

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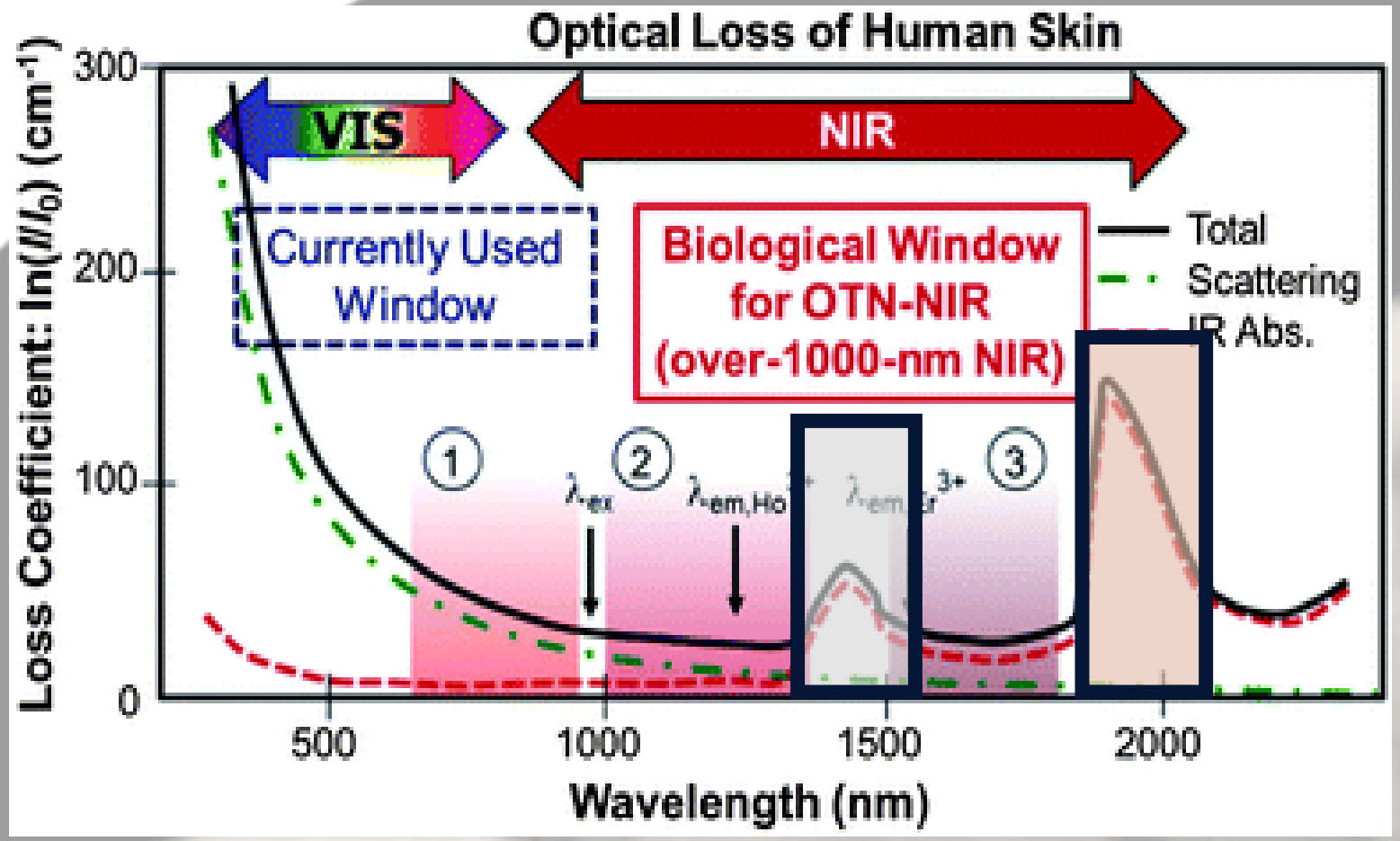
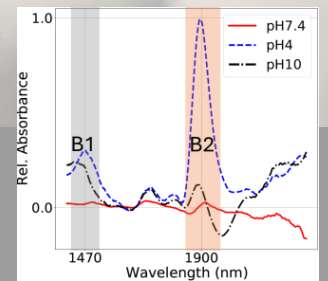
Going non-invasive and going spectroscopic

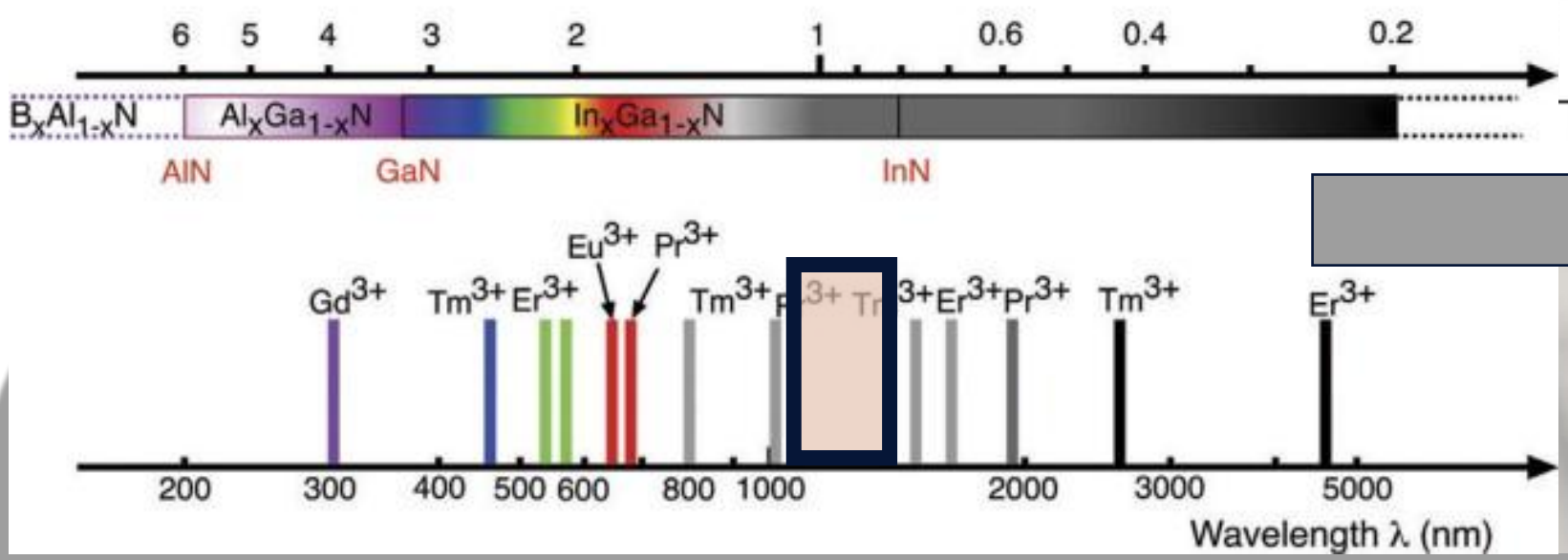


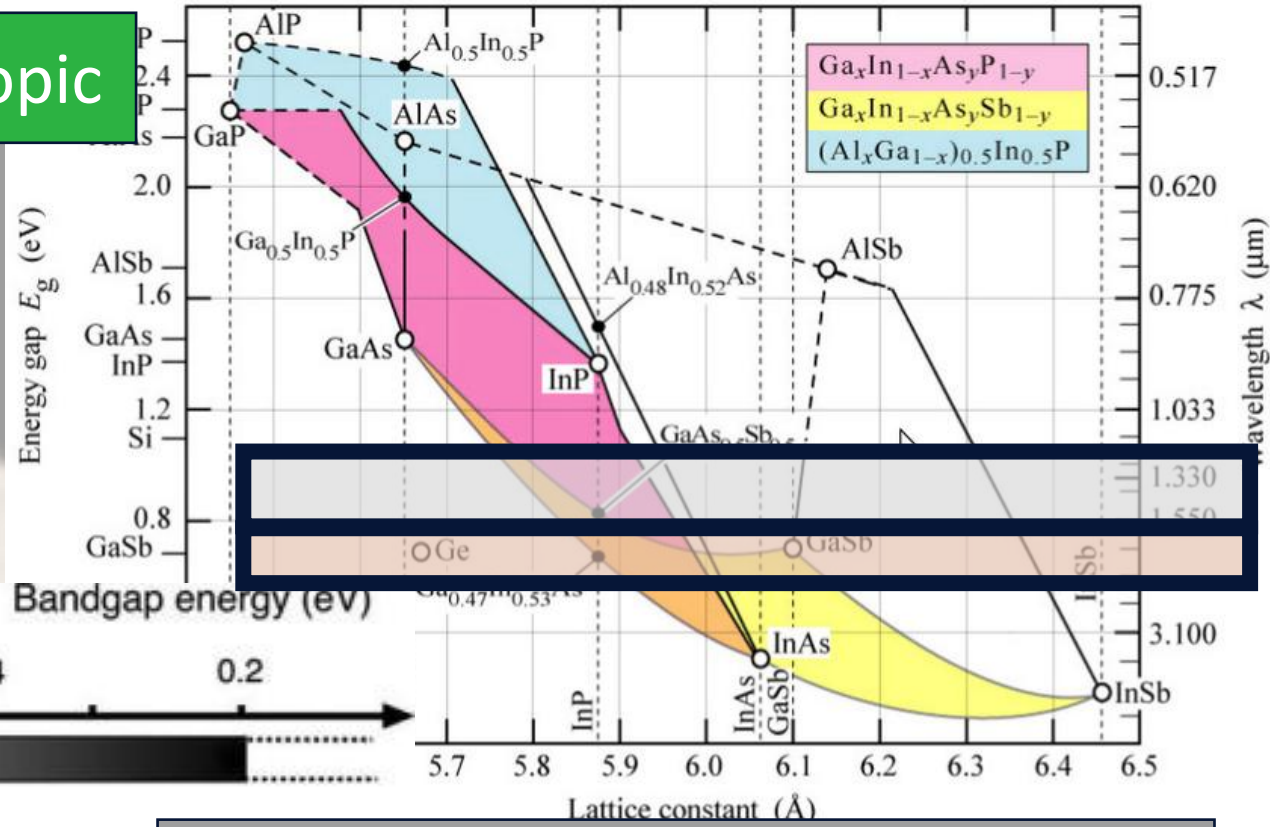


Hemmer, Eva, et al. "Upconverting and NIR emitting rare earth based nanostructures for NIR-bioimaging." Nanoscale 5.23 (2013): 11339-11361.
Steckl, Andrew & Park, Jeong & Zavada, J.. (2007). Prospects for rare earth doped GaN lasers on Si. Materials Today - MATER TODAY.
Gucmann, Filip. (2015). GaAs-based MOS Structures. 10.13140/RG.2.1.4012.1685.
F.C. Garcia Gunning et al, "Key enabling technologies for optical communications at 2000 nm," Appl. Opt. 57, F64 (2018).

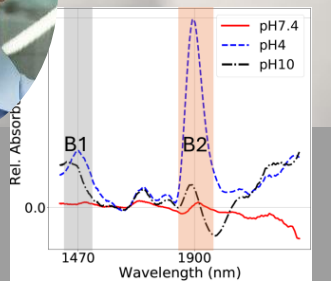
Going non-invasive and going spectroscopic

Optical communication





Photonics



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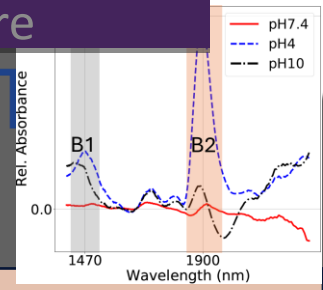
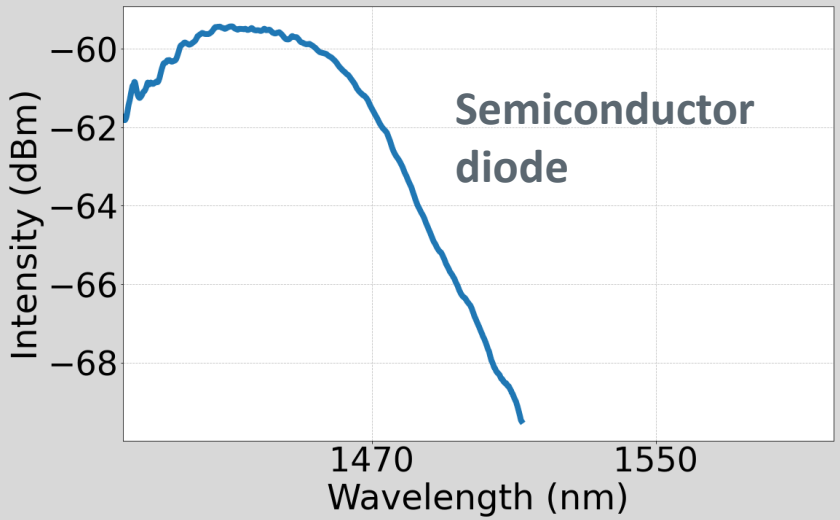
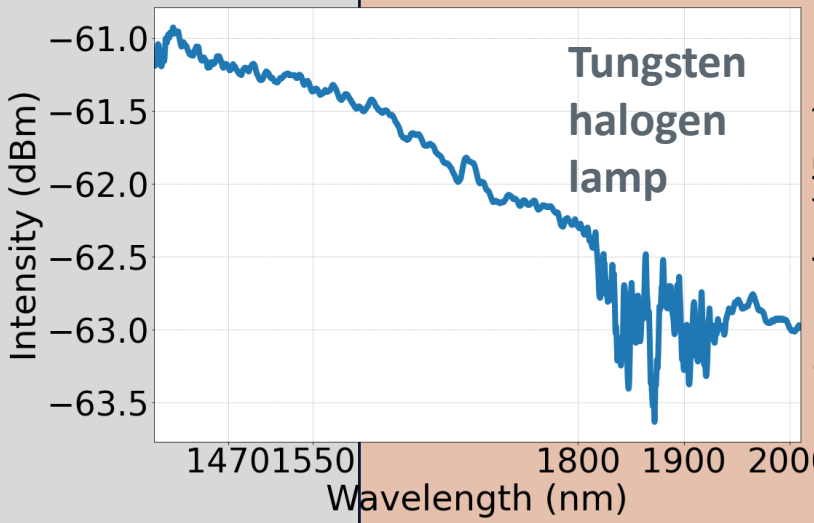
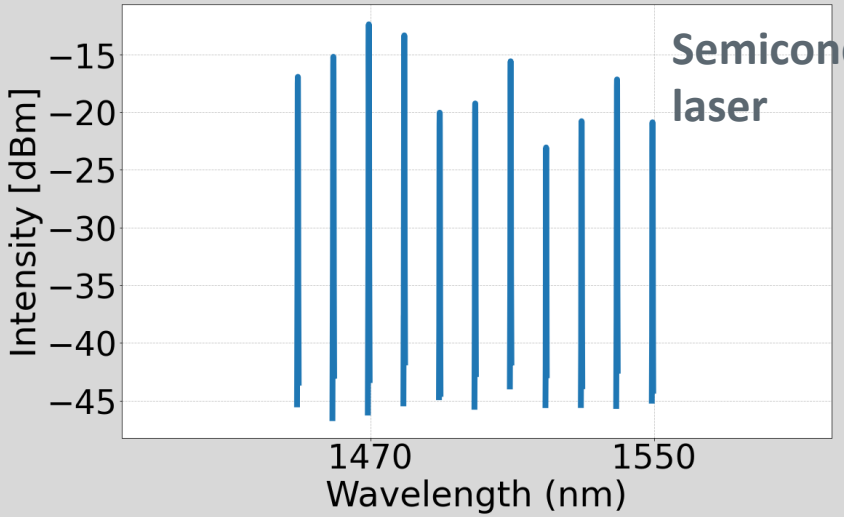
What's available?



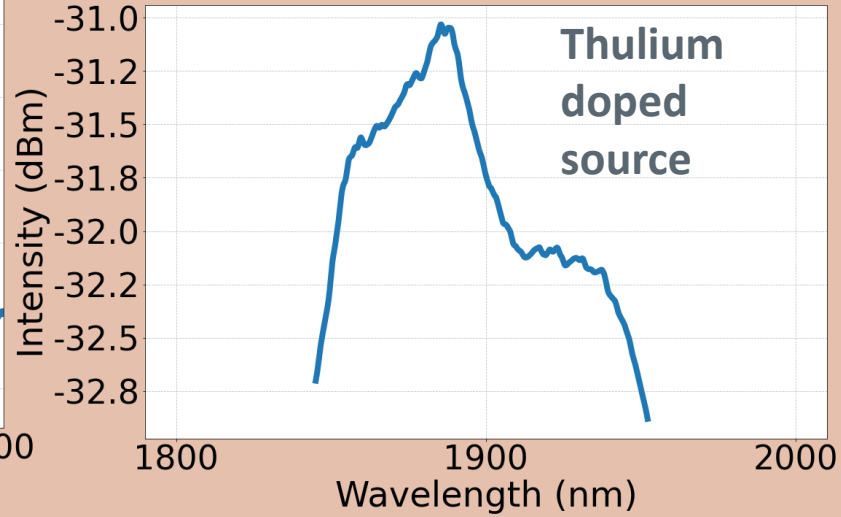
B1 band – 1470 nm

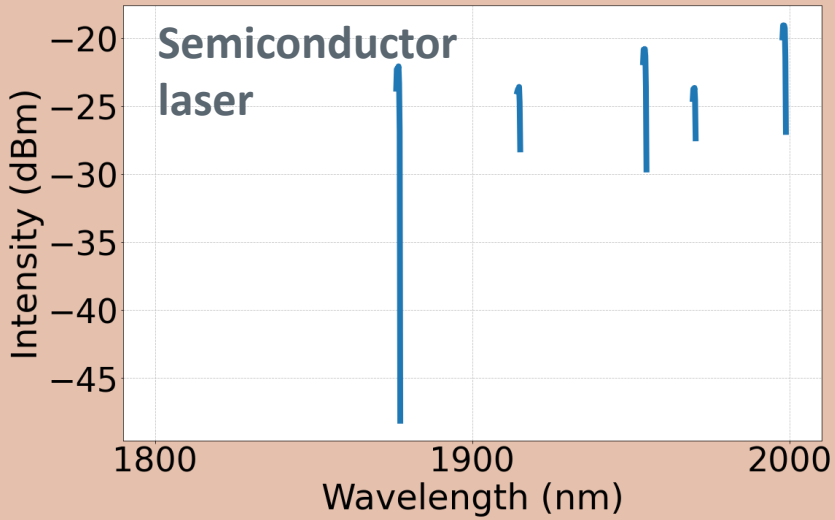






B2 band – 1900 nm





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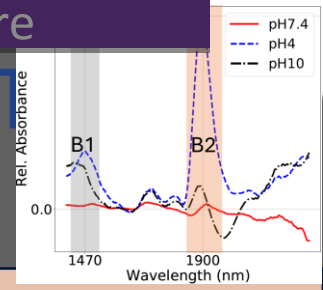
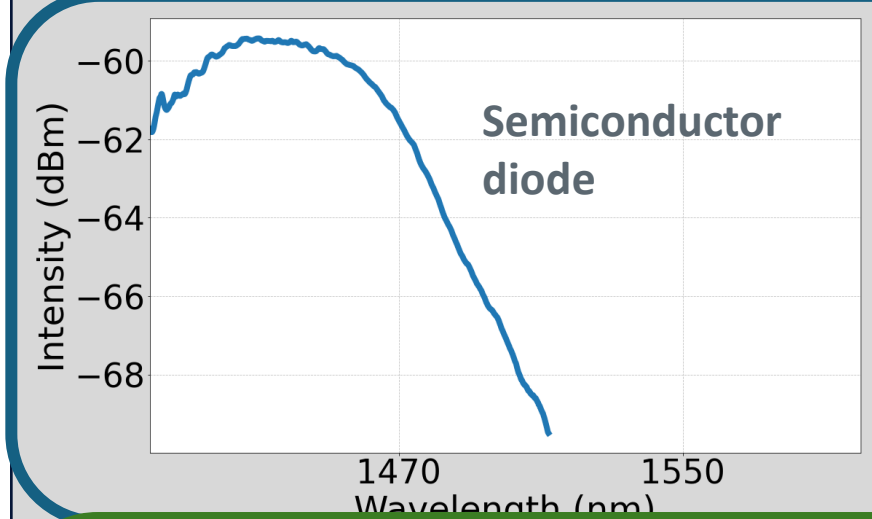
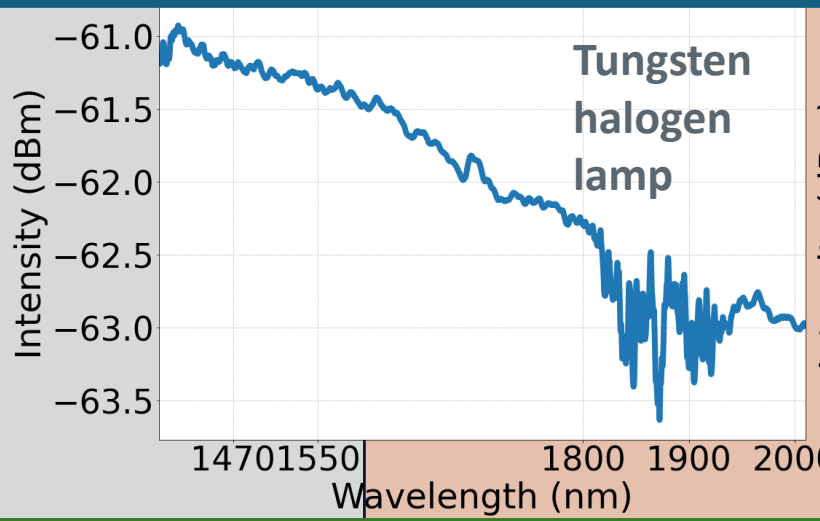
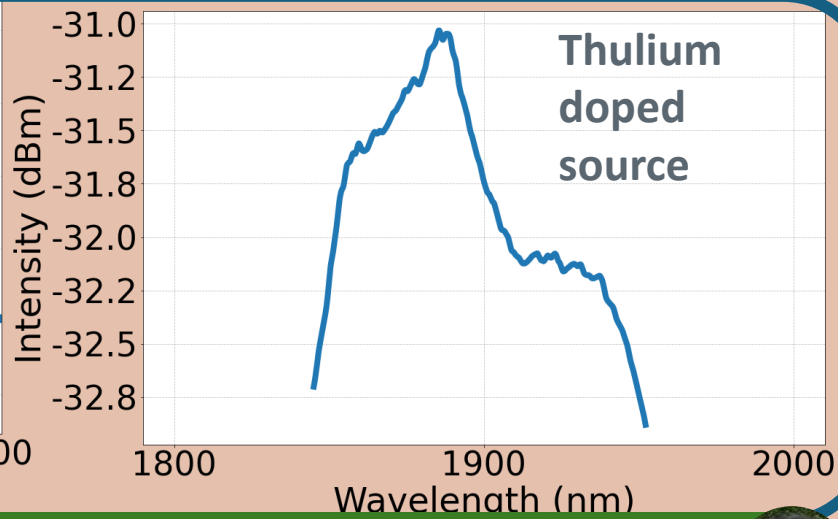


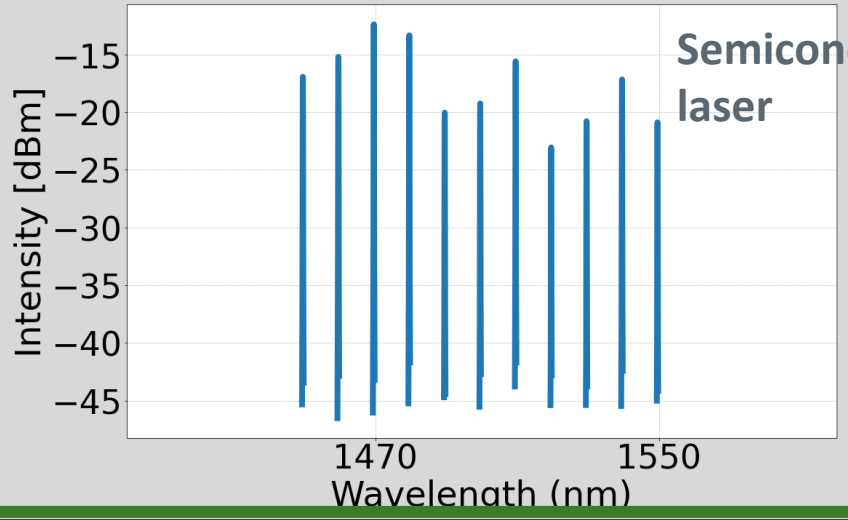
B1 band – 1470 nm

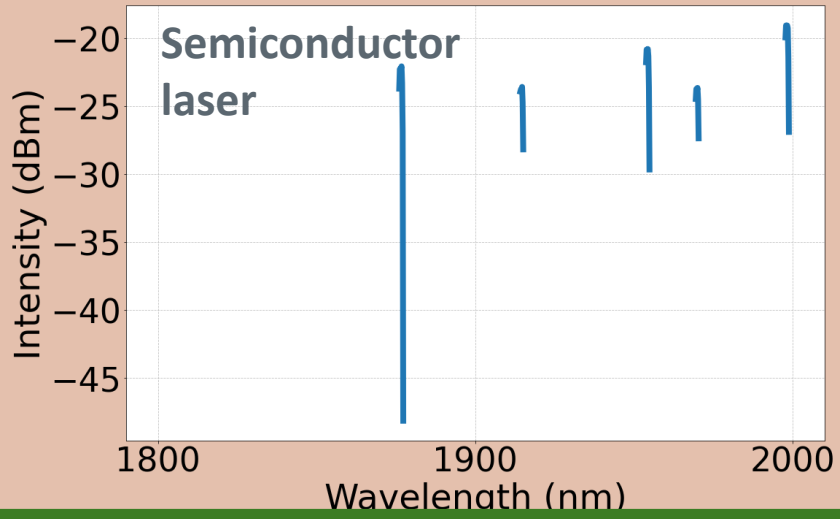
B2 band – 1900 nm



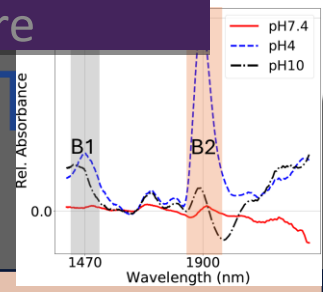




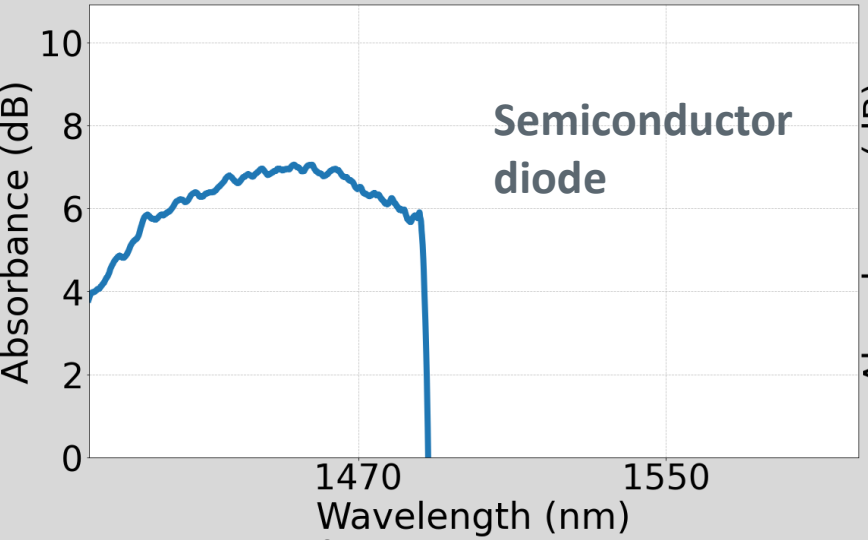


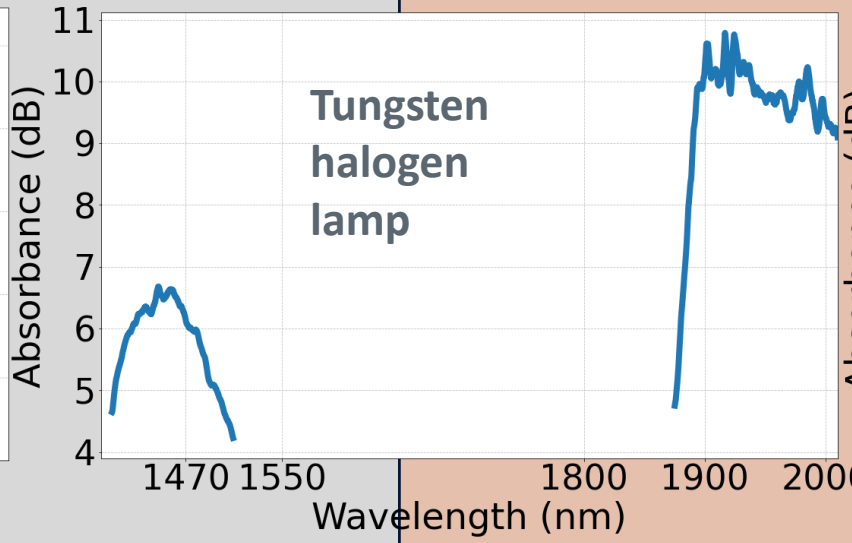


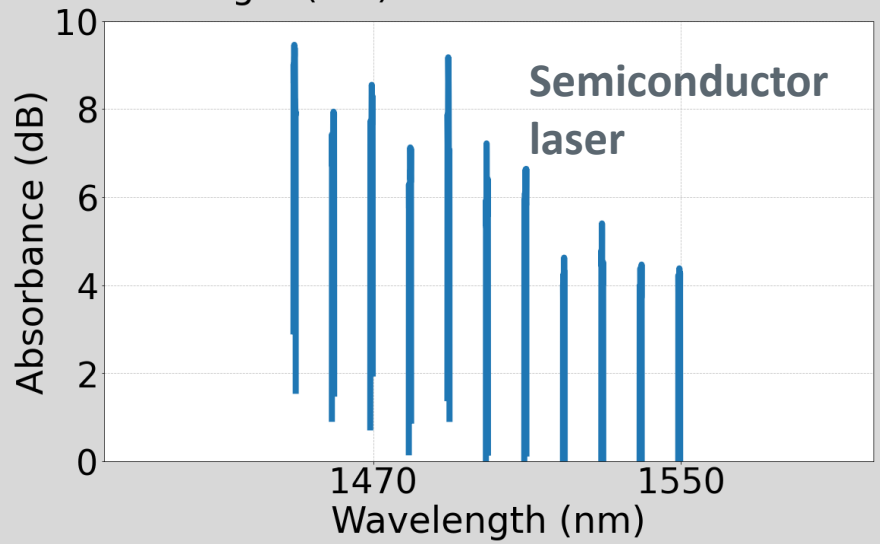
Interaction with water



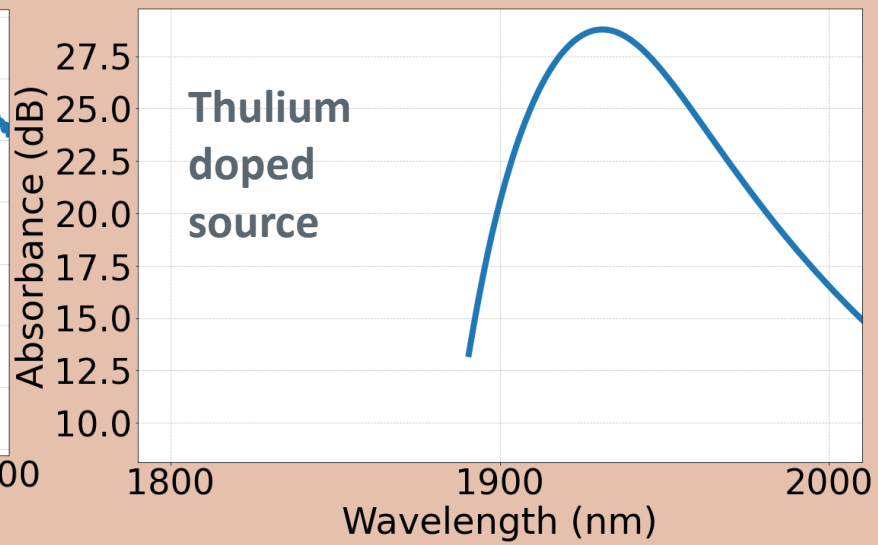
B1 band – 1470 nm

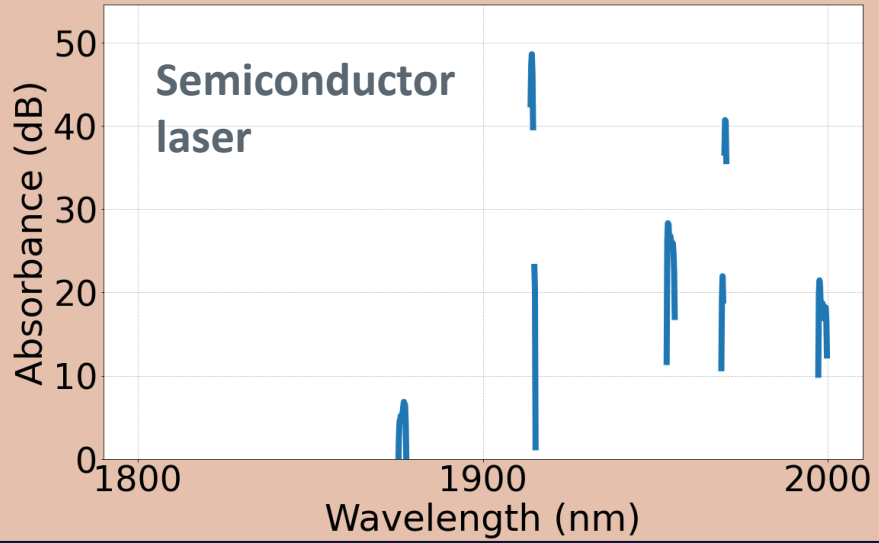




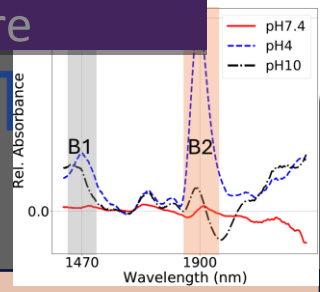


B2 band – 1900 nm

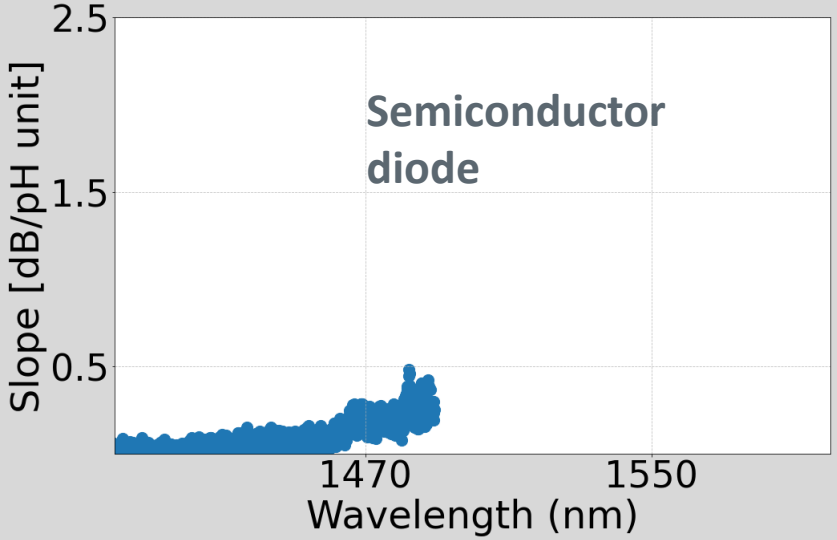


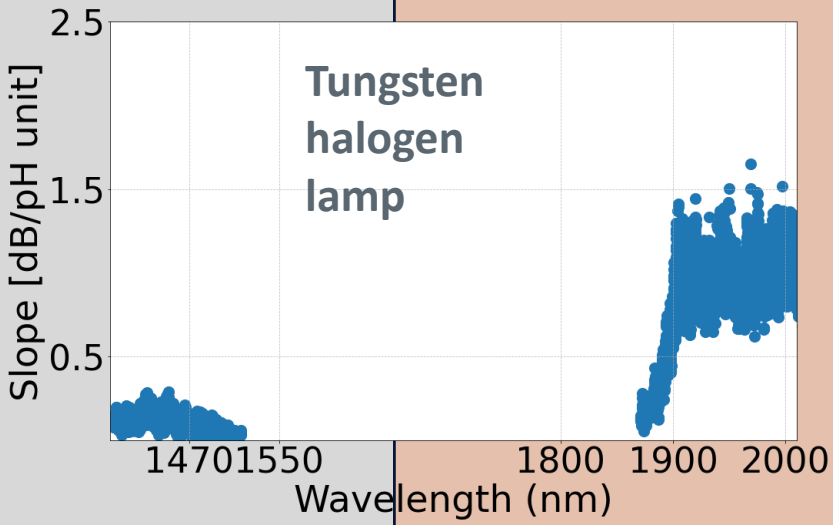


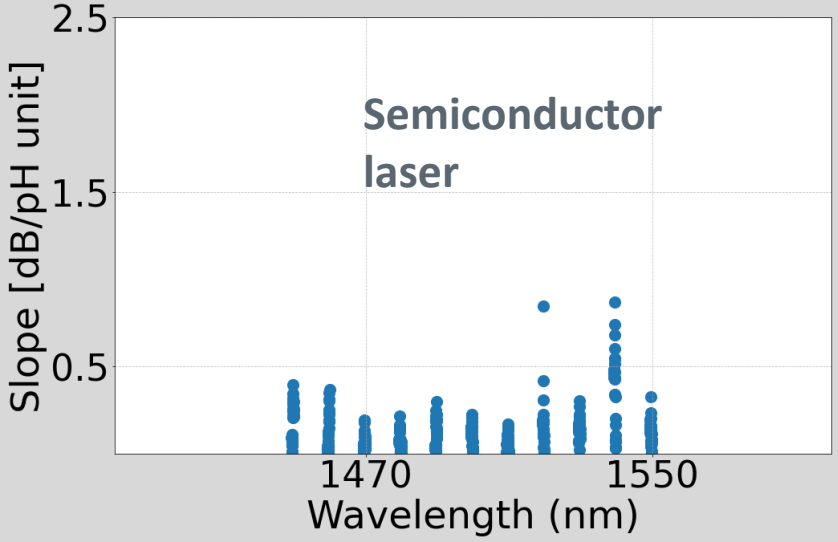
Sensitivity



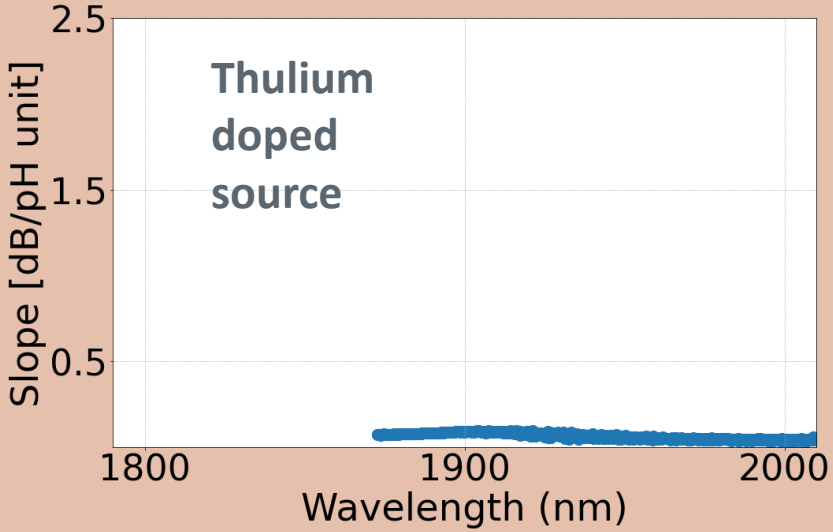
B1 band – 1470 nm

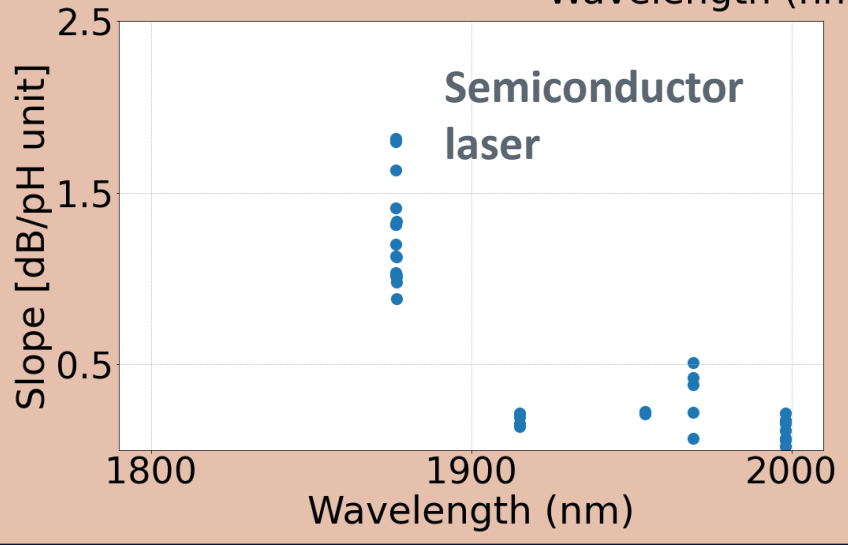






B2 band – 1900 nm





Conclusions and future work

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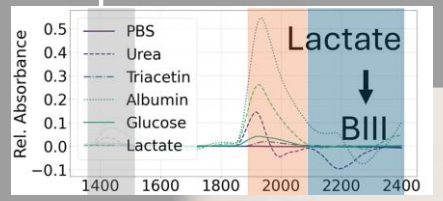
Lactate assessment

Conclusions

1. Clear bands for detection of biomarkers in simple medium.
2. Ability to measure multiple biomarkers simultaneously.
3. Phantoms with multiple interferences are more realistic models to test robustness of a band.

Future work

1. In-silico phantoms
2. Improved photonics benchtop



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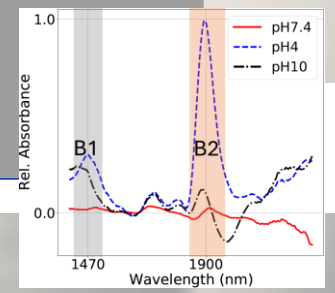
pH assessment

Conclusions

1. Two bands – B1 (1470 nm) and B2 (1900 nm) – accessible with technology
2. Penetration depth comparable to current sensors
3. Selection of broadband and laser sources in B1 and B2

Future work

1. Increased pH sensitivity with lasers
2. Depth achievable



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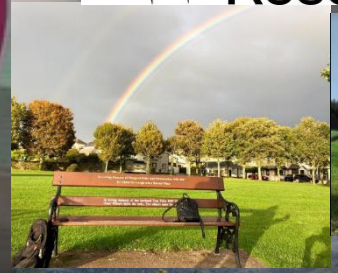


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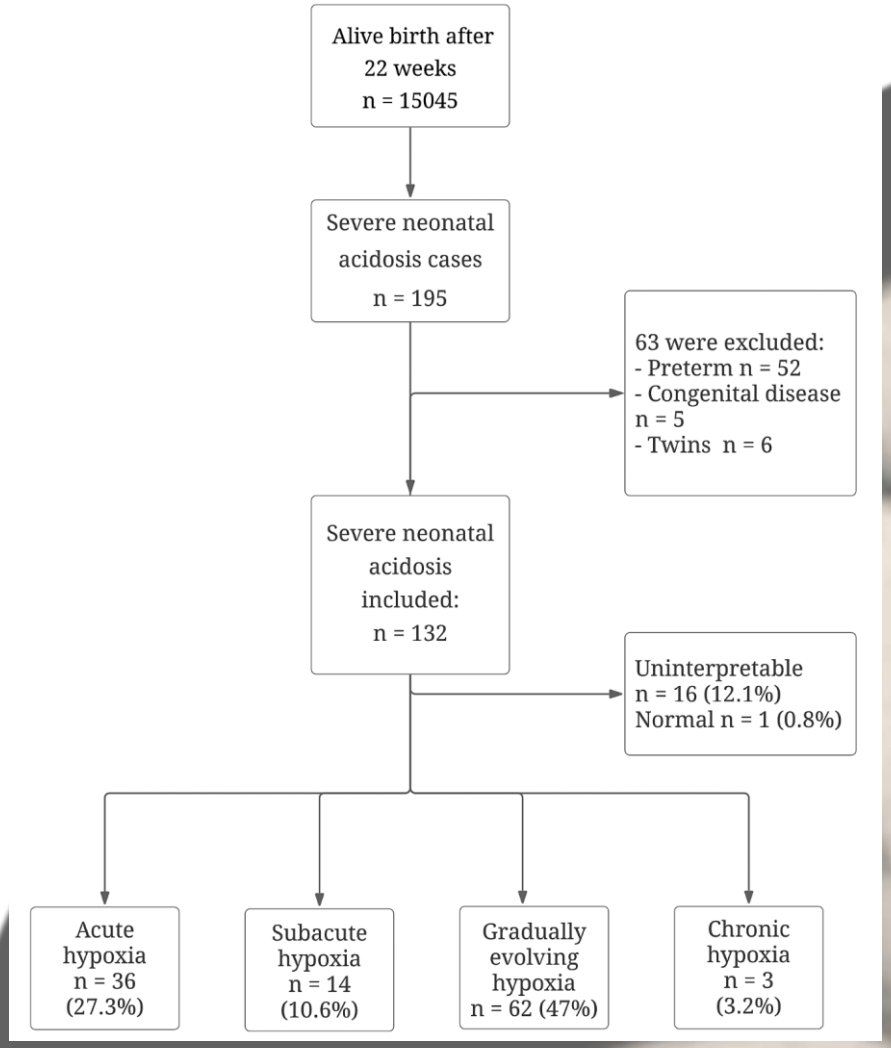

hypoxia, hypoglycaemia and Hypothermia. These resources can be found WHO | Survive and thrive: transforming care for every small and sick new-born

Key "Think Points" for Learning

- Keep them **Pink.** Ensure infant breathing is adequate to maintain oxygenation and understand consequences of ineffective respiratory effort causing **Hypoxia.**
- Keep them **Sweet**. Ensure infant glucose levels are maintained for energy, understand the consequences of low blood sugar and prevent **Hypoglycaemia.**
- Keep them **warm.** Ensure that the infant is kept warm, not affected by heat loss and cold stress, ensuring **Hypothermia** is prevented.

Descourvieres L, Ghesquiere L, Drumez E, et al. Types of intrapartum hypoxia in the newborn at term with metabolic acidemia: A retrospective study. *Acta Obstet Gynecol Scand*. 2022; 101: 1276-1281. doi:10.1111/aogs.14436

Hitchcock, J. (2022). Hypoxia, Hypoglycemia, Hypothermia; The Three Hs - A Global Perspective on Early Care of the Newborn. In: Petty, J., Jones, T., van den Hoogen, A., Walker, K., Kenner, C. (eds) Neonatal Nursing: A Global Perspective. Springer, Cham. https://doi.org/10.1007/978-3-030-91339-7_16