CIS II: Project 15

MOUSE OPTICAL PROPERTIES SUMMARY

UPDATED: 4.13.2016

Notes and Conventions

Cow: Green
Human: Blue
Mouse: Red
Pig: Black
Rat: Purple

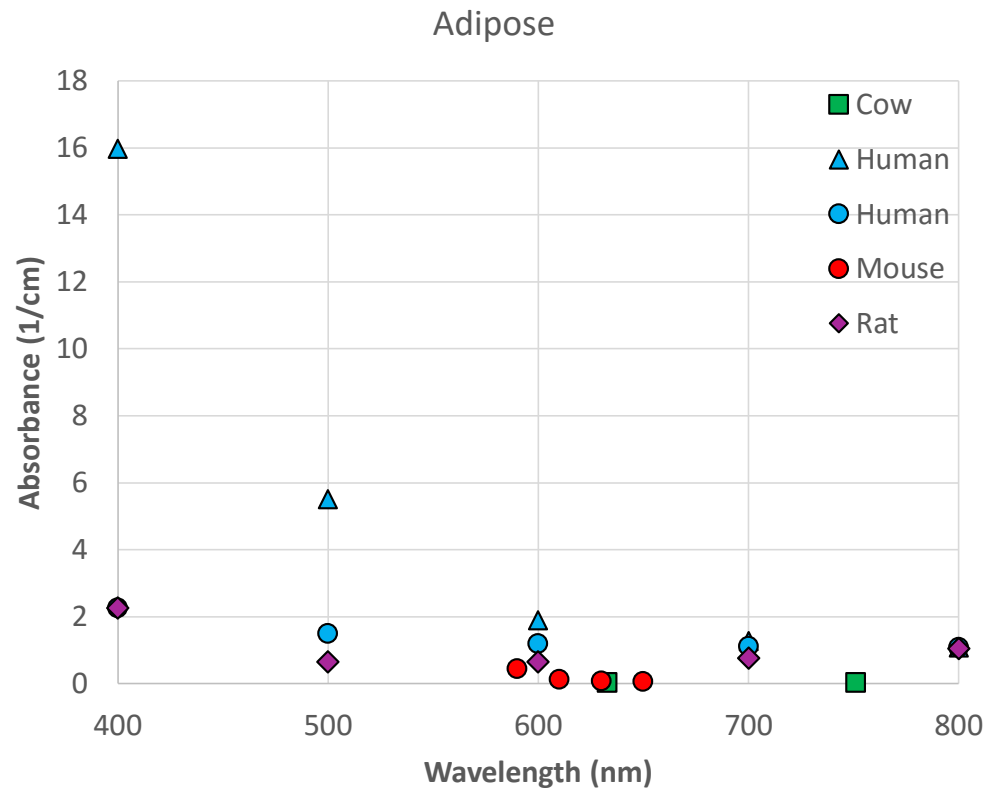| Using the following parameters for Alexandrakis calculations:				
Prahl S A 2001	http://omlc.ogi.edu/spectra/index.html (Oregon Medical Laser Clinic)			
	http://omlc.org/spectra/hemoglobin/summary.html			
lambda(nm)	HbO2 molar extinction(1/cm/M)	Hb molar extinction(1/cm/M)	HbO2 absorption (1/cm)	Hb absorption (1/cm)
590	14400.8	28324.4	77.12800558	151.7002167
610	1506	9443.6	8.065855814	50.57816465
630	610	5148.8	3.267046512	27.57601488
650	368	3750.12	1.970939535	20.08494502

Also, please note that Jacques citations can be ambiguous about the species from which a data point is taken.

Adipose μ_a

Adipose

Human: Bashkatov 2011
- Citing Salomatina 2006 ▲
  - Integrating sphere, inverse Monte Carlo method
- Citing Bashkatov 2005 ●
  - Integrating sphere, inverse adding-doubling method

Mouse: Alexandrakis 2005 ●
- Citing Mitic 1994, Kienle 1996, Holboke 2000, Srinivasan 2003
- **Previously used in SARRP Red Journal article**
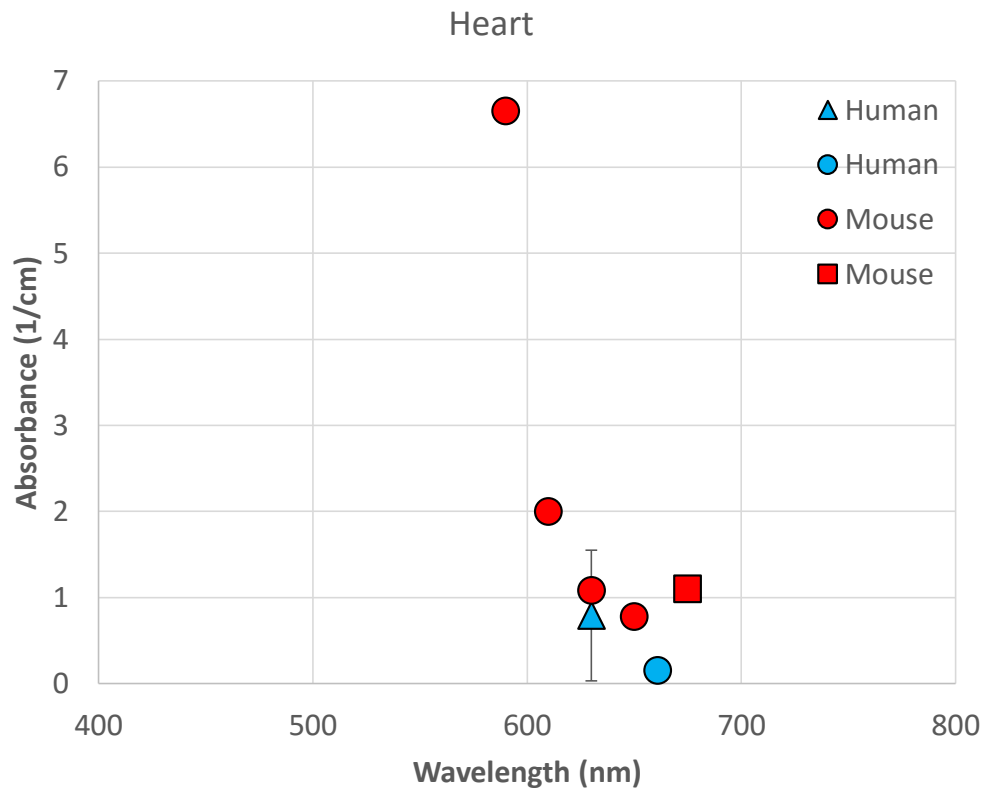
Rat: Bashkatov 2011 ◆
- Citing Bashkatov 2005
  - Integrating sphere, inverse adding-doubling method

Cow: Kienle 1996 ■
- Spatially Resolved Absolute Diffuse Reflectance

Adipose μ$_s$'

Adipose

Reduced Scattering (1/cm) vs Wavelength (nm)

Legend:
- Cow
- Human
- Human
- Human
- Human
- Human
- Human
- Mouse
- Mouse
- Rat

Cow: Kienle 1996
◦ Spatially Resolved Absolute Diffuse Reflectance

Rat: Bashkatov 2011
◦ Citing Bashkatov 2005
   ◦ Integrating sphere, inverse adding-doubling method

Mouse: Alexandrakis 2005
◦ Citing Mitic 1994, Kienle 1996, Holboke 2000, Srinivasan 2003

Mouse: Wang 2015
◦ Citing Jacques 2013
◦ **Previously used in SARRP Red Journal article**

Human: Bashkatov 2011
◦ Citing Salomatina 2006
   ◦ Integrating sphere, inverse Monte Carlo method
◦ Citing Bashkatov 2005
   ◦ Integrating sphere, inverse adding-doubling method

Human: Jacques 2013
◦ Citing Salomatina 2006 (Fat)
◦ Citing Salomatina 2006 (Adipocytes)
◦ Citing Simpson 1998
◦ Citing Peters 1990

Heart μ_a

Heart

Chart: Absorbance (1/cm) vs Wavelength (nm), titled "Heart". Legend: △ Human, ● Human, ● Mouse, ■ Mouse

Mouse: Alexandrakis 2005 ●
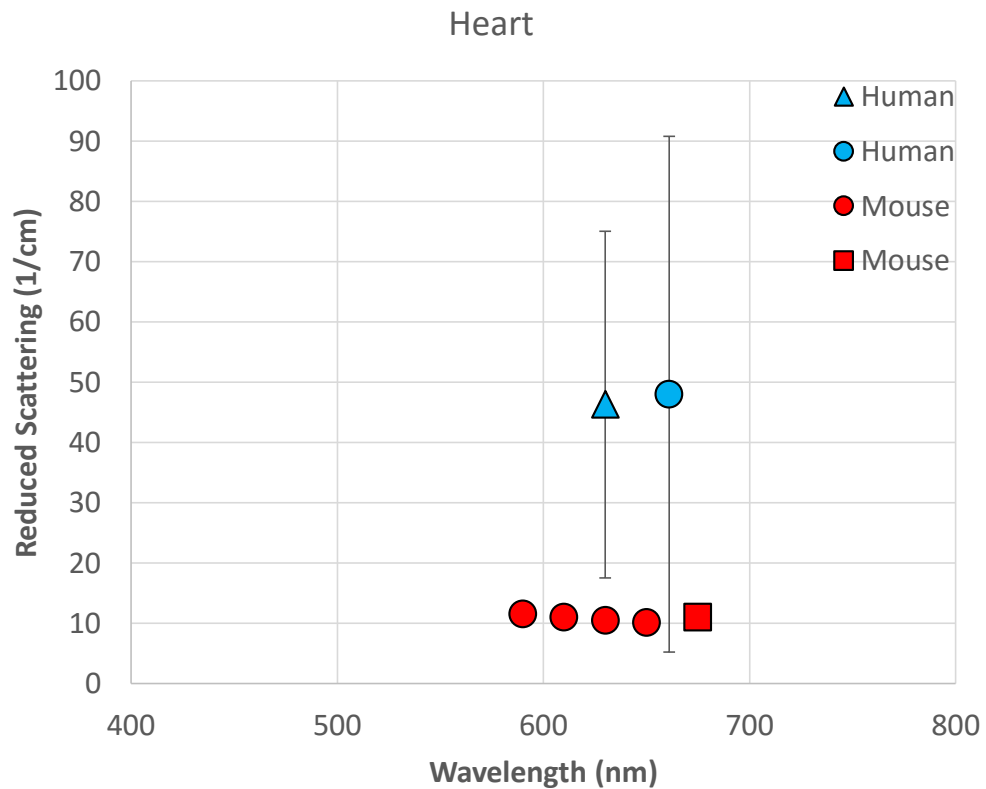- Citing Swartling 2003

Mouse: Wang Ge 2006 for range 650-700 nm ■
- Citing Alexandrakis 2005 for formula
  - No citation for μ for Hb, HbO_2, H_2O

Human: Sandell 2011
- Citing Dimofte 2009 △
  - Reported as range 0.03 to 1.55 cm^{-1}, not standard deviation
  - Eight patients, properties determined before and after PDT by analysis of diffuse reflectance spectra
- Citing Dimofte 2010 ●
  - Reported as range 0.12 to 0.18 cm^{-1}, not standard deviation
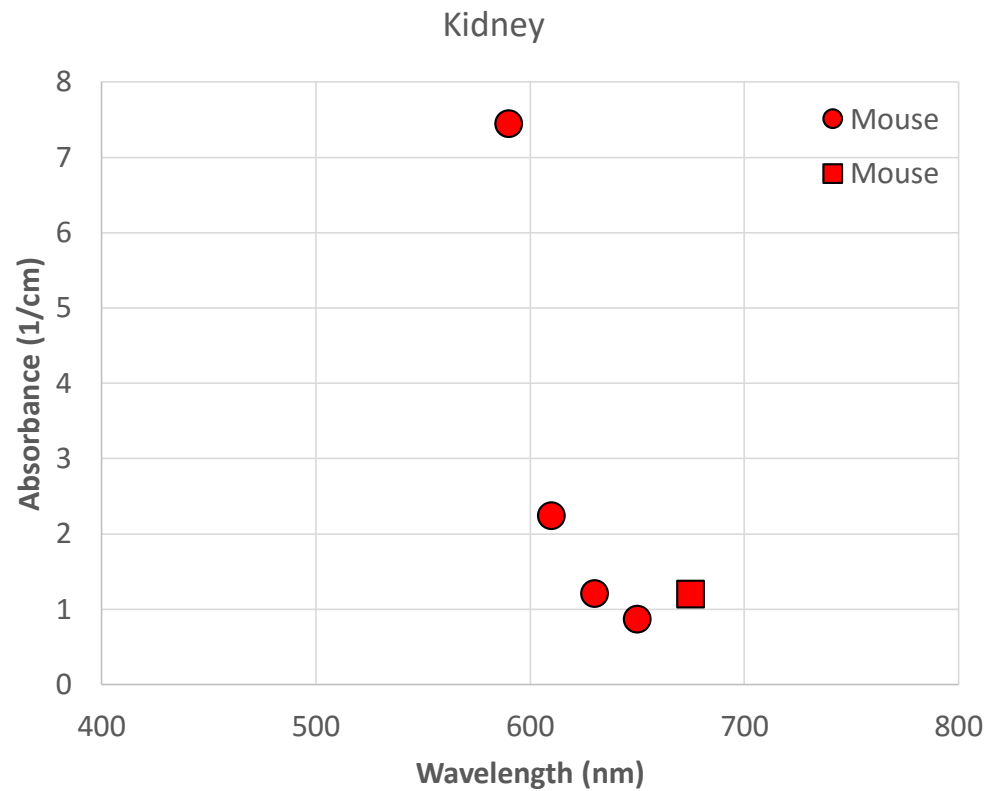 - Five patients, properties determined before and after PDT by analysis of diffuse reflectance spectra

Heart μ_s'

Human: Sandell 2011

◦ Citing Dimofte 2009 ▲

　◦ Reported as range 17.56 to 75.06 cm^{-1}, not standard deviation

　◦ Eight patients, properties determined before and after PDT by analysis of diffuse reflectance spectra

◦ Citing Dimofte 2010 ●

　◦ Reported as range 5.22 to 90.8 cm^{-1}, not standard deviation

　◦ Five patients, properties determined before and after PDT by analysis of diffuse reflectance spectra

Mouse: Alexandrakis 2005 ●

◦ Citing Swartling 2003

Mouse: Wang Ge 2006 for range 650 – 750 nm ■

◦ Citing Alexandrakis 2005 for formula
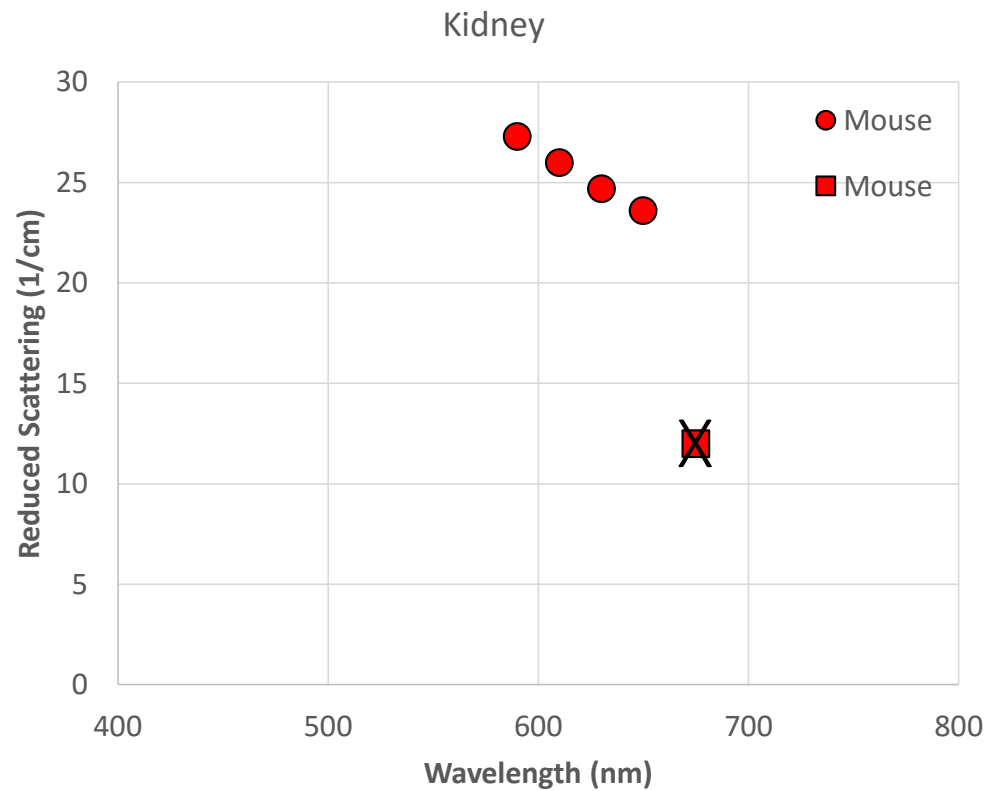
Kidney μ_a

Kidney

Mouse: Alexandrakis 2005 ●
- Citing Solonenko 2002

Mouse: Wang Ge 2006 for range 650-700 nm ■
- Citing Alexandrakis 2005 for formula
  - No citation for μ for Hb, HbO_2, H_2O

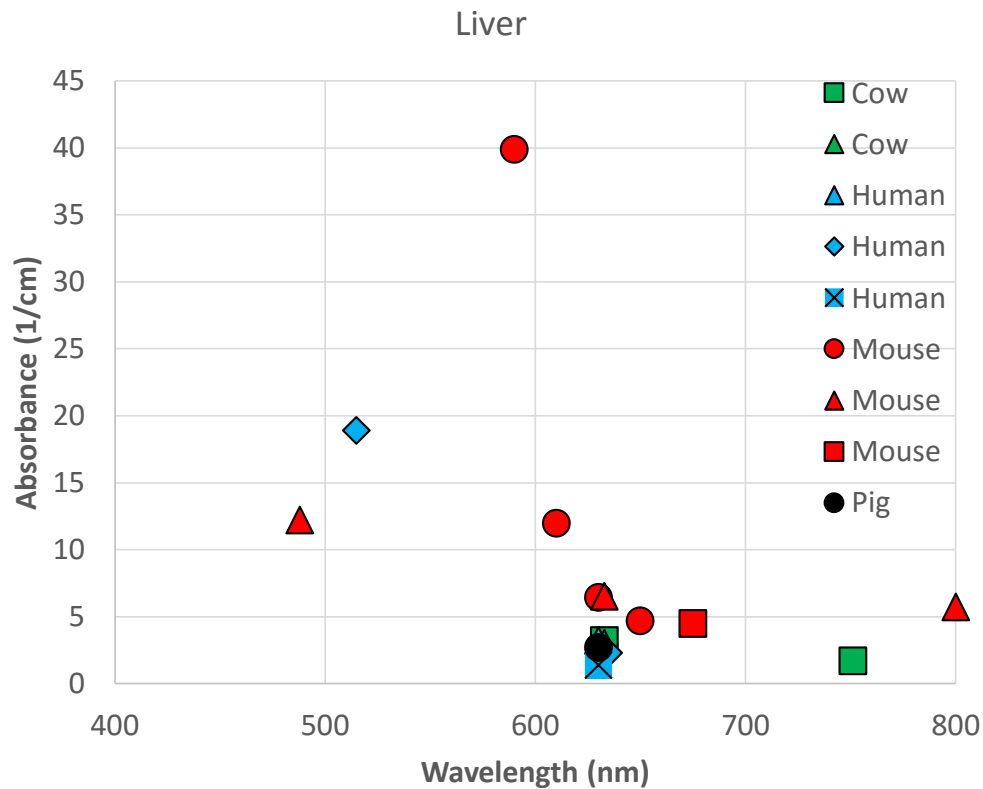# Kidney μ_s'

Kidney

Alexandrakis 2005 ●

◦ Citing Solonenko 2002

Wang Ge 2006 for range 650-700 nm ■

◦ Citing Alexandrakis 2005 for formula

◦ Note: likely to be error

◦ $(41700 \text{ mm}^{-1}) (650)^{-1.51}$ = 2.359 mm^{-1} = 23.6 cm^{-1}

◦ $(41700 \text{ mm}^{-1}) (700)^{-1.51}$ = 2.109 mm^{-1} = 21.1 cm^{-1}

Liver μ_a

Liver

(Chart: Absorbance (1/cm) vs Wavelength (nm), 400–800 nm, legend: Cow ■ green, Cow ▲ green, Human ▲ blue, Human ◆ blue, Human ✖ blue, Mouse ● red, Mouse ▲ red, Mouse ■ red, Pig ● black)

Cow: Cheong 1990 ▲
- Citing Karagiannes 1989

Human: Cheong 1990
- Citing Andreola 1988 ▲
- Citing Marchesini 1989 ◆

Mouse: Alexandrakis 2005 ●
- Citing Karagiannes 1989, Marchesini 1989, Parsa 1989, Kienle 1996, Beek 1997, Ritz 2001, Srinivasan 2003

Pig: Cheong 1990 ●
- Citing Wilson 1986

Mouse: Cheong 1990 ▲
- Citing Parsa 1989
  - See figure to right for hump around 550 nm

Mouse: Wang Ge 2006 ■
- Citing Alexandrakis 2005

Cow: Kienle 1996 ■

Human: Sandell 2011
- Citing Wang HW 2003, 2005 ✖
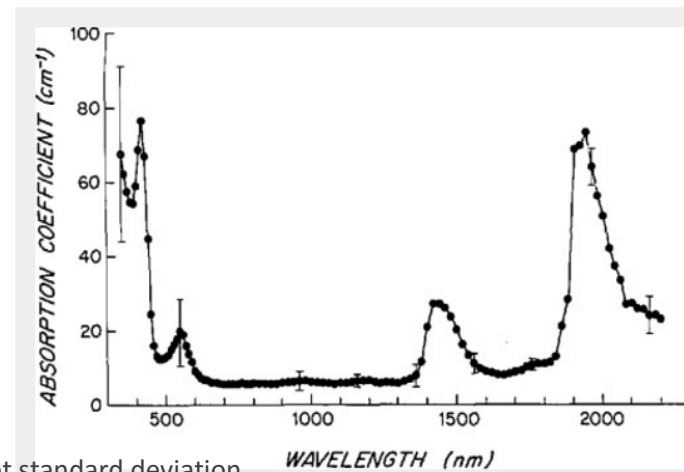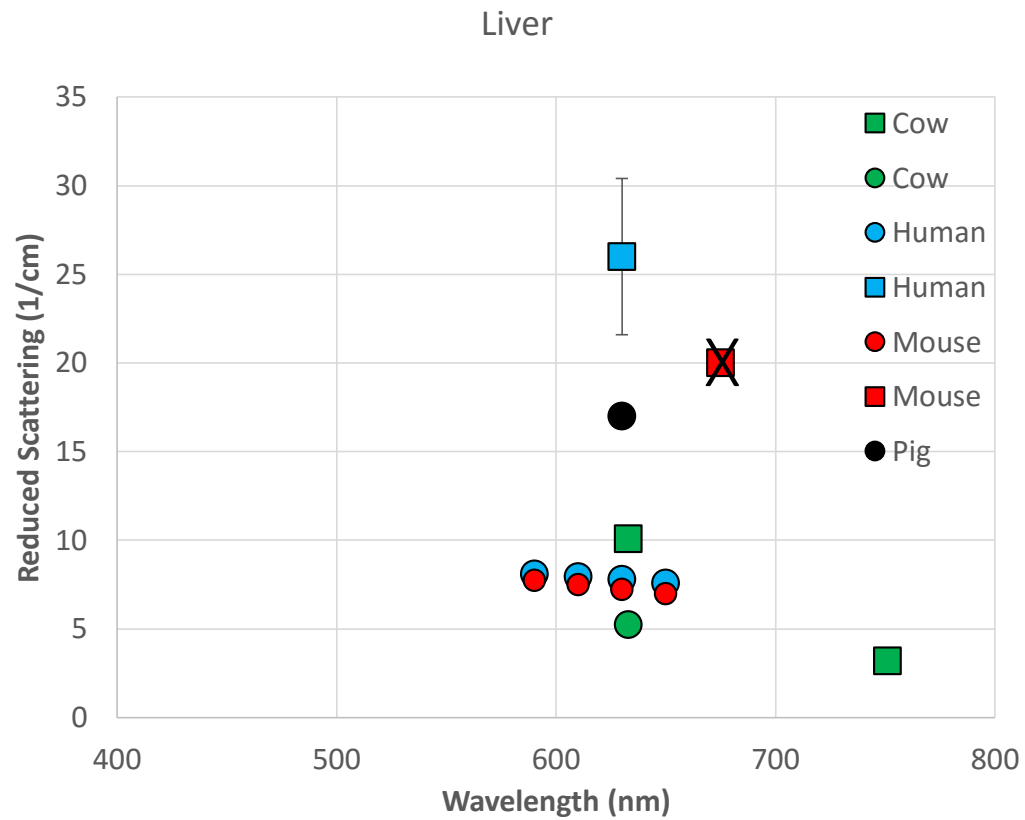- Reported as range 1.15 to 1.56 cm^{-1}, not standard deviation

Fig. 1
Average value of μ_a over the 350–2200-nm wavelength range. Vertical bars represent one standard deviation and appear at 200-nm intervals for clarity.

Liver μ_s'

Liver

(plot: Wavelength (nm) vs Reduced Scattering (1/cm))

Human: Sandell 2011 ■
- Citing Wang HW 2003, 2006
  - In situ measurement in PDT patients
- Reported as range 21.6 to 30.4 cm^{-1}, not standard deviation

Mouse: Wang Ge 2006 for range 650-700 nm ■
- Citing Alexandrakis 2005 for formula
- Note: likely to be error
  - (629 mm^{-1}) (650)$^{-1.05}$ = 0.7 mm^{-1} = 7 cm^{-1}
  - (792 mm^{-1}) (700)$^{-1.05}$ = 0.648 mm^{-1} = 6.48 cm^{-1}

Pig: Cheong 1990 ●
- Citing Wilson 1986
  - PDT study

Cow: Cheong 1990 ●
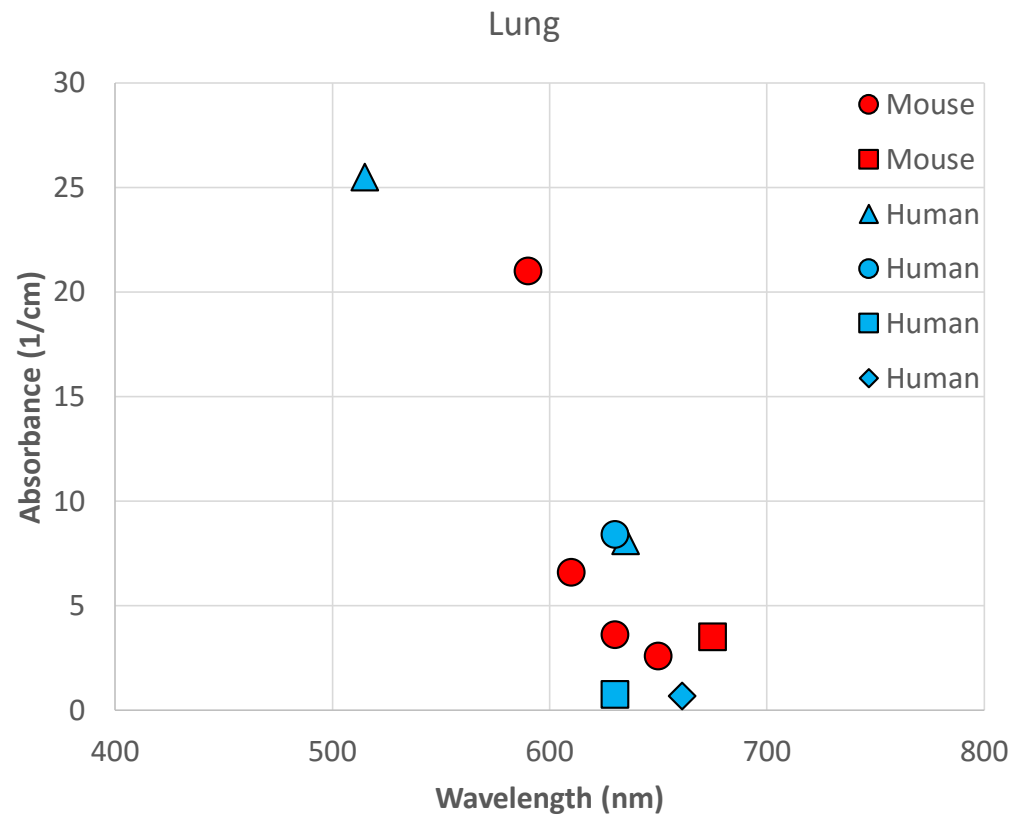- Citing Karagiannes 1989

Human: Jacques 2013 ●
- Citing Parsa 1989

Mouse: Alexandrakis 2005 ●
- Citing Karagiannes 1989, Marchesini 1989, Parsa 1989, Kienle 1996, Beek 1997, Ritz 2001, Srinivasan 2003

Cow: Kienle 1996 ■

Lung μ$_a$

Lung

Human: Cheong 1990
- ◦ Citing Marchesini 1989 ▲
  - ◦ Integrating sphere, goniophotometry
- ◦ Citing Andreola 1988 ●

Mouse: Alexandrakis 2005 ●
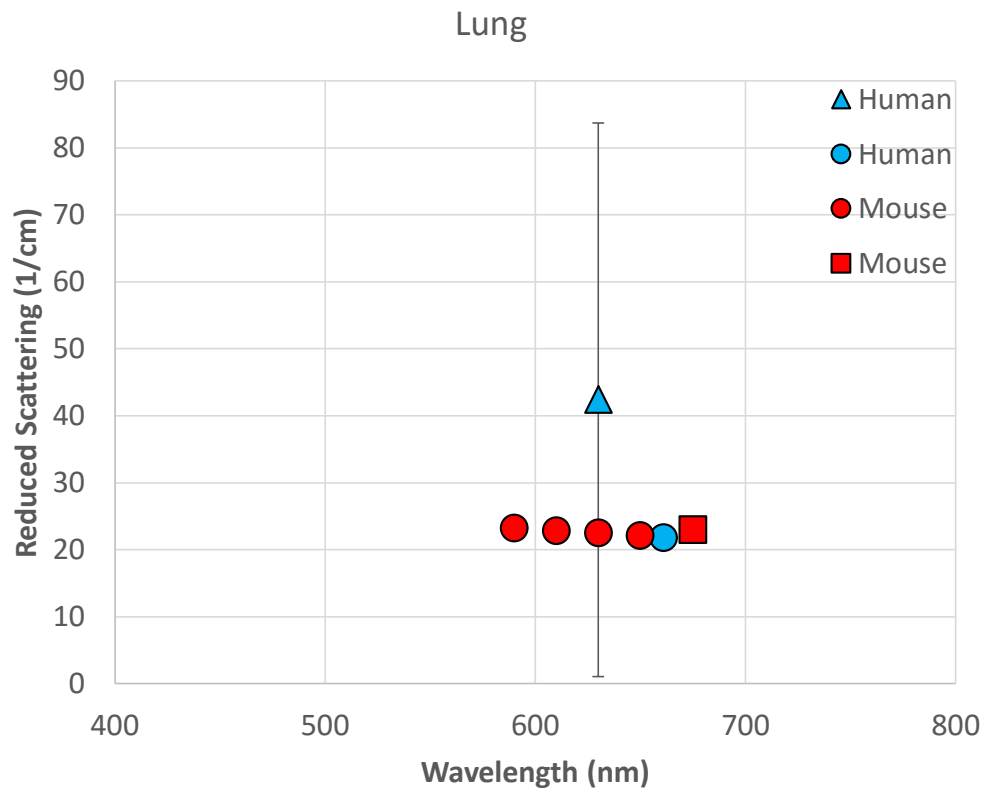- ◦ Citing Beek 1997, Srinivasan 2003

Mouse: Wang Ge 2006 for range 650-700 nm ■

- ◦ Citing Alexandrakis 2005 for formula

Human: Sandell 2011
- ◦ Citing Dimofte 2009 ■
  - ◦ Reported as range 0.16 to 1.36 cm^{-1}, not standard deviation
- ◦ Citing Dimofte 2010 ◆
  - ◦ Reported as range 0.49 to 0.88 cm^{-1}, not standard deviation

Lung μ_s'

Lung

Human: Sandell 2011
- Citing Dimofte 2009 ▲
  - Reported as range 1.07 to 83.81 cm^{-1}, not standard deviation
- Citing Dimofte 2010 ●
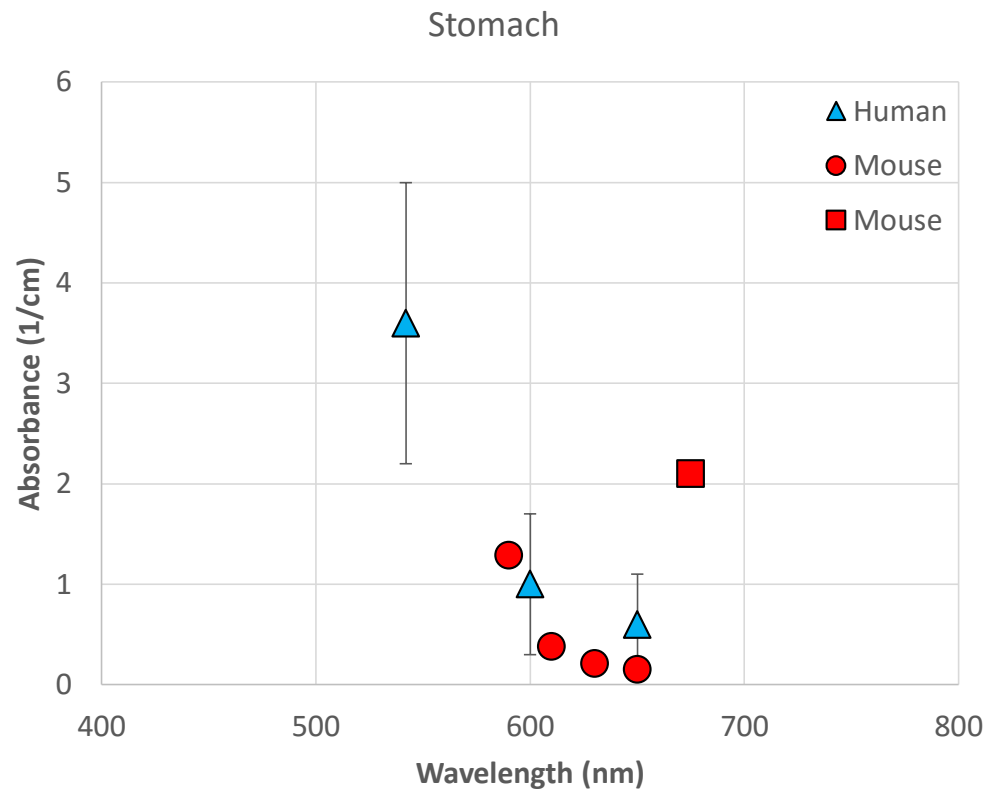 - Reported as range 21.14 to 22.52 cm^{-1}, not standard deviation

Mouse: Alexandrakis 2005 ●
- Citing Beek 1997, Srinivasan 2003

Mouse: Wang Ge 2006 ■
- Citing Alexandrakis 2005 for formula

Stomach μ_a

Stomach

Mouse: Wang Ge 2006 for range 650-700 nm ■

◦ Citing Alexandrakis 2005 for formula

◦ Note: possible error
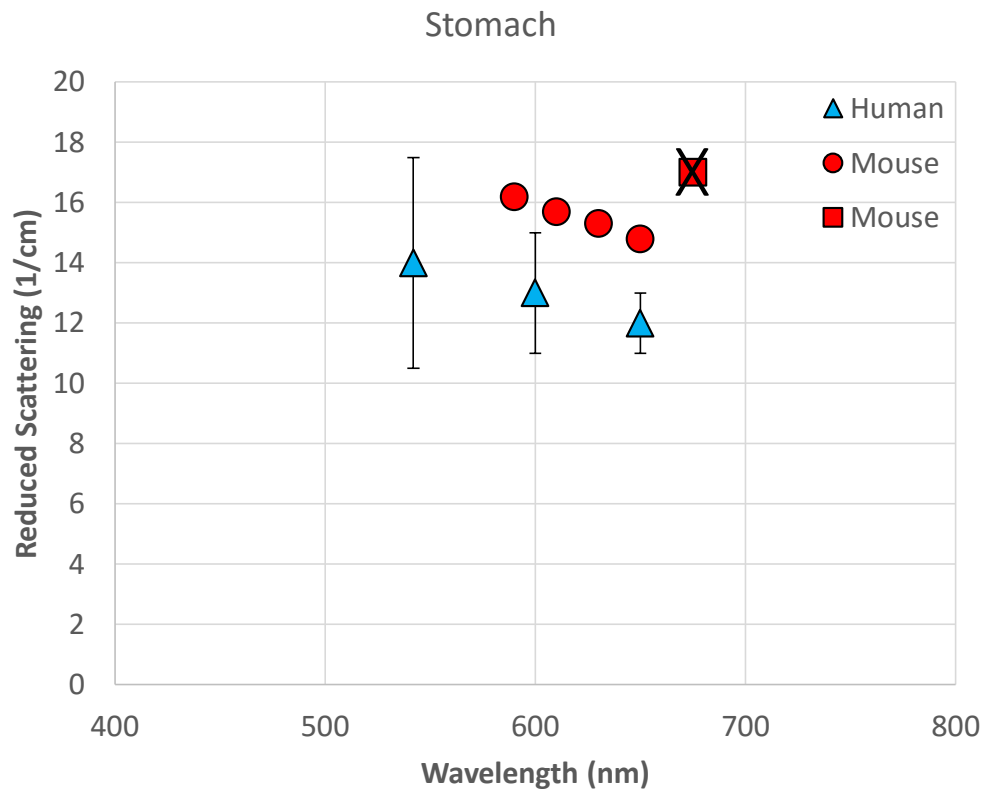
  ◦ No citation for μ for Hb, HbO_2, H_2O

Human: Welch 2011 ▲

◦ Citing Thueler 2003

  ◦ Spatially resolved diffuse reflectance

◦ ±1.4, ±0.7, ±0.5 at 542 nm, 600 nm, 650 nm, respectively

Mouse: Alexandrakis 2005 ●

◦ Citing Thueler 2003

Stomach μ_s'

Mouse: Wang Ge 2006 for range 650-700 nm 🟥

- Citing Alexandrakis 2005 for formula
- Note: likely to be error
  - $(792 \text{ mm}^{-1})(650)^{-0.97} = 1.48 \text{ mm}^{-1} = 14.8 \text{ cm}^{-1}$
  - $(792 \text{ mm}^{-1})(700)^{-0.97} = 1.38 \text{ mm}^{-1} = 13.8 \text{ cm}^{-1}$

Mouse: Alexandrakis 2005 🔴

- Citing Thueler 2003

Human: Welch 2011 🔺

- Citing Thueler 2003
  - Spatially resolved diffuse reflectance
- ±3.5, ±2.0, ±1.0 at 542 nm, 600 nm, 650 nm, respectively

Summary

λ (nm)		Alexandrakis						SARRP Red Journal	
		Adipose	Heart	Kidney	Liver	Lung	Stomach	Abdomen*	Tumor**
590	μ_a (cm^{-1})	0.431	6.65	7.45	39.90	21.08	1.29	0.431	3.8
	μ_s' (cm^{-1})	12.900	11.60	27.3	7.75	23.25	16.26	15.300	9.0
610	μ_a (cm^{-1})	0.127	2.00	2.24	11.99	6.63	0.38	0.127	2.3
	μ_s' (cm^{-1})	12.700	11.00	26	7.50	22.85	15.74	14.600	7.6
630	μ_a (cm^{-1})	0.069	1.08	1.21	6.45	3.59	0.21	0.069	1.9
	μ_s' (cm^{-1})	12.480	10.50	24.7	7.23	22.46	15.25	14.000	6.9
650	μ_a (cm^{-1})	0.050	0.78	0.87	4.67	2.61	0.15	0.050	1.6
	μ_s' (cm^{-1})	12.270	10.10	23.6	7.00	22.09	14.80	13.500	6.6

* SARRP abdomen μ_a from Alexandrakis 2005, abdomen μ_s' from Jacques 2013
** SARRP tumor μ_a and μ_s' from Honda 2011

Main Sources

1987 Jacques SL, Prahl SA. Modeling optical and thermal distributions in tissue during laser irradiation. Lasers Surg Med. 1987;6:494–503.

1990 Cheong WF, Prahl SA, Welch AJ. A review of the optical properties of biological tissues. IEEE Journal of Quantum Electronics. 1990;26:2166–2185.

1993 Firbank M, Hiraoka M, Essenpreis M, et al. Measurement of the optical properties of the skull in the wavelength range 650-950 nm. Phys. Med. Biol. 1993;38:503–510.

1996 Kienle A, Lilge L, Patterson MS, et al. Spatially resolved absolute diffuse reflectance measurements for noninvasive determination of the optical scattering and absorption coefficients of biological tissue. Appl. Opt. 1996;35:2304–2314.

2001 Torricelli A, Pifferi A, Taroni P, et al. In vivo optical characterization of human tissues from 610 to 1010 nm by time-resolved reflectance spectroscopy. Phys. Med. Biol. 2001;46:2227–2237.

2005 Alexandrakis G, and Rannou FR, and Chatziioannou AF. - Tomographic bioluminescence imaging by use of a combined optical-PET (OPET) system: A computer simulation feasibility study. - Physics in Medicine and Biology(- 17):- 4225.

2006 Wang Ge, Cong Wenxiang , Durairaj Kumar, Qian Xin, Shen Haiou, Sinn Patrick, Hoffman Eric, McLennan Geoffrey, and Henry Michael, "In vivo mouse studies with bioluminescence tomography," Opt. Express 14, 7801-7809 (2006)

2011 Sandell, J.L., & Zhu, T.C. (2011). A review of in-vivo optical properties of human tissues and its impact on PDT. Journal of Biophotonics, 4(11-12), 773-787.

2011 Honda N, Ishii K, Terada T, Nanjo T, Awazu K; Determination of the tumor tissue optical properties during and after photodynamic therapy using inverse monte carlo method and double integrating sphere between 350 and 1000 nm. J. Biomed. Opt. 0001;16(5):058003-058003-7. doi:10.1117/1.3581111.

2011 Bashkatov, A.N., Genina, E.A., Tuchin, V.V. (2011). Optical properties of skin, subcutaneous, and muscle tissues: A review. Journal of Innovative Optical Health Sciences, 04(01), 9-38.

2011 Welch AJ, Gemert MJC. Optical-thermal response of laser-irradiated tissue. Dordrecht: Springer; 2011.

2013 Jacques SL. Optical properties of biological tissues: a review. Phys. Med. Biol. 2013;58:R37–R61.