

## References (database v5.0, 21.08.2025)

**References for the thermal, physical, and dielectric properties** listed in our material properties database. Values for tissues of which the properties are not available in the literature are substituted with values from other tissues. In these cases, the tissue used for the value is listed instead of a reference. The rationale for each individual substitution is provided in the Rationale for Tissue Substitutions.

Tissue	Heat Capacity	Thermal Conductivity	Heat Transfer Rate	Dielectric Properties
Adrenal Gland	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Bernardi et al., 2003</a>	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Williams and Leggett, 1986</a>	<a href="#">Peyman et al., 2012</a>
Air	<a href="#">Bernardi et al., 2003</a> <a href="#">Collins et al., 2004</a> See Fluid Properties Database, Equation	<a href="#">Bernardi et al., 2003</a> <a href="#">Collins et al., 2004</a> See Fluid Properties Database, Equation	Not in Database	<a href="#">Gabriel et al., 1996</a>
Bile	<a href="#">Bernardi et al., 2003</a> <a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">Gabriel et al., 1996</a>
Blood	<a href="#">Bernardi et al., 2003</a> <a href="#">McIntosh and Anderson, 2010</a>	<a href="#">Collins et al., 2004</a> <a href="#">Duck, 1990</a> <a href="#">Holmes Appendix A-B</a> <a href="#">McIntosh and Anderson, 2010</a> <a href="#">Van Den Berg et al., 1983</a>	<a href="#">Collins et al., 2004</a>	<a href="#">Gabriel et al., 1996</a>
Blood Plasma	<a href="#">Duck, 1990</a>	<a href="#">Duck, 1990</a>	Not in Database	Not in Database
Blood Serum	Not in Database	Not in Database	Not in Database	Not in Database
Blood Vessel Wall	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">Williams et al., 1988</a>	<a href="#">Gabriel et al., 1996</a>

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Tissue	Heat Capacity	Thermal Conductivity	Heat Transfer Rate	Dielectric Properties
Bone	Bone (Cortical)	Bone (Cortical)	Bone (Cortical)	Bone (Cortical)
Bone (Cancellous)	Collins et al., 2004 McIntosh and Anderson, 2010	Clattenburg et al., 1975 Collins et al., 2004 McIntosh and Anderson, 2010	Collins et al., 2004 McIntosh and Anderson, 2010 Williams and Leggett, 1986	Gabriel et al., 1996
Bone (Cortical)	Duck, 1990 McIntosh and Anderson, 2010 Van Leeuwen et al., 1999	Collins et al., 2004 McIntosh and Anderson, 2010	Collins et al., 2004	Gabriel et al., 1996
Bone Marrow (Red)	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Williams and Leggett, 1986	Gabriel et al., 1996
Bone Marrow (Yellow)	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	Gabriel et al., 1996
Brain	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010 Williams and Leggett, 1986	Cerebellum
Brain (Grey Matter)	McIntosh and Anderson, 2010 Bernardi et al., 2003 Duck, 1990	McIntosh and Anderson, 2010	Collins et al., 2004 McIntosh and Anderson, 2010	Gabriel et al., 1996
Brain (White Matter)	McIntosh and Anderson, 2010 Duck, 1990 Bernardi et al., 2003	McIntosh and Anderson, 2010	Collins et al., 2004 McIntosh and Anderson, 2010	Gabriel et al., 1996
Breast Fat	Fat	Hamilton, 1998	Delille et al., 2002	Gabriel et al., 1996
Breast Gland	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	McIntosh and Anderson, 2010	Thyroid Gland

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Bronchi	Blood Vessel Wall	Blood Vessel Wall	<a href="#">Parsons et al., 1985</a> <a href="#">Wu et al., 1985</a>	Trachea
Bronchi lumen	Air	Air	None	Air
Cartilage	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Bernardi et al., 2003</a>	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Bernardi et al., 2003</a>	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">Gabriel et al., 1996</a>
Cerebellum	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">Gabriel et al., 1996</a>
Cerebrospinal Fluid	<a href="#">Bernardi et al., 2003</a> <a href="#">Van Leeuwen et al., 1999</a>	<a href="#">Collins et al., 2004</a> <a href="#">Van Leeuwen et al., 1999</a> <a href="#">Bernardi et al., 2003</a>	None	<a href="#">Gabriel et al., 1996</a>
Cervix	Uterus	Uterus	N/A	<a href="#">Gabriel et al., 1996</a>
Commissura Anterior	Brain (White Matter)	Brain (White Matter)	Brain (White Matter)	Brain (White Matter)
Commissura Posterior	Brain (White Matter)	Brain (White Matter)	Brain (White Matter)	Brain (White Matter)
Connective Tissue	Tendon/Ligament and Bone (Cortical)	Tendon/Ligament and Bone (Cortical)	N/A	Tendon\Ligament
Diaphragm	Muscle	Muscle	<a href="#">Guenette et al., 1985</a>	Muscle
Ductus Deferens	Blood Vessle Wall	Blood Vessle Wall	Ureter/Urethra	Blood Vessel Wall
Dura	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">Gabriel et al., 1996</a>
Epididymis	Testis	Testis	Testis	Testis
Esophagus	<a href="#">McIntosh et al., 2010</a>	<a href="#">Collins et al., 2004</a>	<a href="#">Barnes et al., 1983</a>	Stomach
Esophagus Lumen	Air	Air	None	Air
Extracellular Fluids	<a href="#">Duck, 1990</a>	<a href="#">Duck, 1990</a>	None	Cerebrospinal Fluid
Eye (Aqueous Humor)	<a href="#">Scott, 1998</a>	<a href="#">Duck, 1990</a>	None	Cerebrospinal Fluid
Eye (Choroid)	Blood	<a href="#">Blood</a>	<a href="#">Xuan et al., 1999</a>	Blood
Eye (Ciliary Body)	Muscle	Muscle	<a href="#">Xuan et al., 1999</a>	Muscle

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Eye (Cornea)	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Bernardi et al., 2003</a>	None	<a href="#">Gabriel et al., 1996</a>
Eye (Iris)	<a href="#">Muscle</a>	Muscle	<a href="#">Caprioli et al., 1984</a> <a href="#">Xuan et al., 1999</a> <a href="#">Werkmeister et al., 2015</a>	Muscle
Eye (Lens)	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Bernardi et al., 2003</a> <a href="#">Van Leeuwen et al., 1999</a>	<a href="#">McIntosh and Anderson, 2010</a> Oezen et al. <a href="#">Bernardi et al., 2003</a>	None	<a href="#">Gabriel et al., 1996</a>
Eye (Retina)	Brain (Grey Matter)	Brain (Grey Matter)	<a href="#">Caprioli et al., 1984</a> <a href="#">Xuan et al., 1999</a>	Brain (Grey Matter)
Eye (Sclera)	<a href="#">Bernardi et al., 2003</a>	<a href="#">Bernardi et al., 2003</a>	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">Gabriel et al., 1996</a>
Eye Lens (Cortex)	Eye(Lens)	Eye(Lens)	None	<a href="#">Gabriel et al., 1996</a>
Eye Lens (Nucleus)	Eye(Lens)	Eye(Lens)	None	<a href="#">Gabriel et al., 1996</a>
Fat	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Van Den Berg et al., 1983</a> <a href="#">Collins et al., 2004</a> <a href="#">Van Leeuwen et al., 1999</a>	<a href="#">McIntosh and Anderson, 2010</a> Duck, 1990 Holmes Appendix A-B <a href="#">Van Leeuwen et al., 1999</a>	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Williams and Leggett, 1986</a>	Fat (Average Infiltrated)
Fat (Average Infiltrated)	Fat	Fat	Fat	<a href="#">Gabriel et al., 1996</a>
Fat (Not Infiltrated)	Fat	Fat	None	<a href="#">Gabriel et al., 1996</a>
Gallbladder	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">Gabriel et al., 1996</a>
Glandula Vesiculosa	Prostate	Prostate	Prostate	Testis
Heart Lumen	Blood	Blood	Blood	Blood

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Heart Muscle	<a href="#">Duck, 1990</a> <a href="#">McIntosh and Anderson, 2010</a>	<a href="#">Duck, 1990</a> <a href="#">McIntosh and Anderson, 2010</a> <a href="#">Van Den Berg et al., 1983</a> <a href="#">Bowman et al., 1975</a> <a href="#">Holmes Appendix A-B</a>	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Williams and Leggett, 1986</a>	<a href="#">Gabriel et al., 1996</a>
Hypophysis	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Williams and Leggett, 1986</a>	Thyroid Gland
Hypothalamus	Brain (Grey Matter)	Brain (Grey Matter)	Brain (Grey Matter)	Brain (Grey Matter)
Intervertebral Disc	Cartilage	Cartilage	Cartilage	<a href="#">Peyman et al., 2010</a>
Kidney	<a href="#">Duck, 1990</a> <a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Williams and Leggett, 1986</a>	<a href="#">Gabriel et al., 1996</a>
Kidney (Cortex)	<a href="#">Holmes et al., 1983</a>	<a href="#">Hamilton, 1998</a> <a href="#">McIntosh and Anderson, 2010</a>	<a href="#">De Bazelaire et al., 2005</a> <a href="#">Holmes Appendix A-B</a> <a href="#">Roberts et al., 1995</a>	Kidney
Kidney (Medulla)	N/A	<a href="#">Bernardi et al., 2003</a>	<a href="#">Holmes Appendix A-B</a> <a href="#">Roberts et al., 1995</a>	Kidney
Large Intestine	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Bernardi et al., 2003</a>	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Bernardi et al., 2003</a> <a href="#">Duck, 1990</a>	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Williams and Leggett, 1986</a>	<a href="#">Gabriel et al., 1996</a>
Large Intestine Lumen	Muscle and Water	Muscle and Water	None	Muscle
Larynx	Cartilage	Cartilage	Cartilage	Cartilage
Liver	<a href="#">Duck, 1990</a> <a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Bowman et al., 1975</a> <a href="#">Duck, 1990</a> <a href="#">Holmes Appendix A-B</a>	<a href="#">Williams and Leggett, 1986</a> <a href="#">McIntosh and Anderson, 2010</a>	<a href="#">Gabriel et al., 1996</a>
Lung	<a href="#">McIntosh and Anderson, 2010</a>	Lung (Inflated)	<a href="#">Cattermole et al., 2017</a> <a href="#">Patel et al., 2021</a> <a href="#">Williams and Leggett, 1986</a>	Lung (Inflated)

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Lung (Deflated)	Lung	<a href="#">Duck, 1990</a> <a href="#">McIntosh and Anderson, 2010</a>	Lung	<a href="#">Gabriel et al., 1996</a>
Lung (Inflated)	Lung	<a href="#">Yang et al., 2020</a>	Lung	<a href="#">Gabriel et al., 1996</a>
Lymph	Not in Database	Not in Database	Not in Database	Not in Database
Lymphnode	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Van Den Berg et al., 1983</a>	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Williams and Leggett, 1986</a>	<a href="#">Peyman et al., 2012</a>
Mandible	Bone (Cortical)	Bone (Cortical)	N/A	Bone (Cortical)
Medulla Oblongata	Brain	Brain	Brain	Cerebellum
Meniscus	Cartilage	Cartilage	Cartilage	Cartilage
Midbrain	Brain	Brain	Brain	Cerebellum
Mucous Membrane	<a href="#">Collins et al., 2004</a>	<a href="#">Collins et al., 2004</a>	<a href="#">McIntosh and Anderson, 2010</a>	Muscle
Muscle	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Van Den Berg et al., 1983</a> <a href="#">Van Leeuwen et al., 1999</a>	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Duck, 1990</a> <a href="#">Collins et al., 2004</a> <a href="#">Bowman et al., 1975</a> <a href="#">Van Leeuwen et al., 1999</a>	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Sekins et al., 1980</a> <a href="#">Williams and Leggett, 1986</a>	<a href="#">Gabriel et al., 1996</a>
Nerve	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">Gabriel et al., 1996</a>
Ovary	Testis	Testis	N/A	<a href="#">Gabriel et al., 1996</a>
Pancreas	<a href="#">McIntosh et al., 2010</a>	<a href="#">Duck, 1990</a> <a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Williams and Leggett, 1986</a>	Thyroid Gland
Patella	Bone (Cortical)	Bone (Cortical)	Bone (Cortical)	Bone (Cortical)
Penis	Blood Vessel Wall	Blood Vessel Wall	<a href="#">Joeng et al., 2002</a>	Blood Vessel Wall
Pharynx	Air	Air	None	Air
Pineal Body	Hypophysis	Hypophysis	Hypophysis	Thyroid gland
Placenta	<a href="#">Hand et al., 2010</a>	N/A	<a href="#">Duncan et al., 1998</a> <a href="#">Wagner et al., 1980</a>	Blood

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Pons	Brain	<a href="#">McIntosh and Anderson, 2010</a>	Brain	Cerebellum
Prostate	<a href="#">Giering et al., 1995</a>	N/A	N/A	Testis
Salivary Gland	Prostate	Prostate	<a href="#">Bisdas et al., 2007</a> <a href="#">Williams and Leggett, 1986</a>	<a href="#">Peyman et al., 2012</a>
SAT (Subcutaneous Fat)	Fat	Fat	Fat	Fat (Average Infiltrated)
Scalp	Skin	Skin	Skin	Skin
Skin	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Collins et al., 2004</a> <a href="#">Bernardi et al., 2003</a> <a href="#">Van Leeuwen et al., 1999</a>	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Duck, 1990</a> <a href="#">Collins et al., 2004</a> <a href="#">Bowman et al., 1975</a> <a href="#">Holmes Appendix A-B</a> <a href="#">Van Leeuwen et al., 1999</a>	<a href="#">Collins et al., 2004</a> <a href="#">McIntosh and Anderson, 2010</a> <a href="#">Williams and Leggett, 1986</a>	<a href="#">Gabriel et al., 1996</a> (Skin Dry)
Skull	Bone	Bone	Bone	Bone
Skull (Cancellous)	Bone (Cancellous)	Bone (Cancellous)	Bone (Cancellous)	Bone (Cancellous)
Skull (Cortical)	Bone (Cortical)	Bone (Cortical)	Bone (Cortical)	Bone (Cortical)
Small Intestine	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Williams and Leggett, 1986</a>	<a href="#">Gabriel et al., 1996</a>
Small Intestine Lumen	Muscle and Water	Muscle and Water	None	Muscle
Spinal Cord	Brain	Brain	<a href="#">McIntosh and Anderson, 2010</a>	Nerve
Spleen	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">Duck, 1990</a> <a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Williams and Leggett, 1986</a>	<a href="#">Gabriel et al., 1996</a>
Stomach	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Williams and Leggett, 1986</a>	<a href="#">Gabriel et al., 1996</a>
Stomach Lumen	Muscle and Water	Muscle and Water	None	Muscle
Tendon\Ligament	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Collins et al., 2004</a>	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Collins et al., 2004</a>	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">Gabriel et al., 1996</a>

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Testis	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">Gabriel et al., 1996</a>
Testis	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Williams and Leggett, 1986</a>	<a href="#">Gabriel et al., 1996</a>
Thalamus	Brain (Grey Matter)	<a href="#">McIntosh et al., 2010</a>	N/A	Brain (Grey Matter)
Thymus	Lymphnode and Fat	Lymphnode and Fat	Lymphnode and Fat	<a href="#">Gabriel et al., 1996</a>
Thyroid Gland	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">Duck, 1990</a> <a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Williams and Leggett, 1986</a>	<a href="#">Gabriel et al., 1996</a>
Tongue	Muscle	Muscle	<a href="#">Nakase et al., 2004</a>	<a href="#">Gabriel et al., 1996</a>
Tooth	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a>	None	Bone (Cortical)
Tooth (Dentine)	<a href="#">Duck, 1990</a> <a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a>	None	Bone (Cortical)
Tooth (Enamel)	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a>	None	Bone (Cortical)
Trachea	Cartilage	Cartilage	Cartilage	<a href="#">Gabriel et al., 1996</a>
Trachea Lumen	Air	Air	None	Air
Ureter\Urethra	Blood Vessel Wall	Blood Vessel Wall	<a href="#">John et al., 2002</a>	Blood Vessel Wall
Urinary Bladder Wall	<a href="#">Bernardi et al., 2003</a> <a href="#">McIntosh and Anderson, 2010</a> <a href="#">Van Den Berg et al., 1983</a>	<a href="#">Bernardi et al., 2003</a> <a href="#">Bowman et al., 1975</a> <a href="#">McIntosh and Anderson, 2010</a> <a href="#">Van Den Berg et al., 1983</a>	<a href="#">Williams and Leggett, 1986</a>	<a href="#">Gabriel et al., 1996</a>
Urine	Water	<a href="#">McIntosh and Anderson, 2010</a>	None	<a href="#">Peyman et al., 2012</a>
Uterus	<a href="#">McIntosh and Anderson, 2010</a>	<a href="#">McIntosh and Anderson, 2010</a> <a href="#">Olsrud et al., 1998</a>	N/A	<a href="#">Gabriel et al., 1996</a>
Vagina	Large Intestine	Large Intestine	<a href="#">Wagner et al., 1980</a>	Large Intestine
Vertebrae	Bone (Cortical)	Bone (Cortical)	Bone (Cortical)	Bone (Cortical)
Water	<a href="#">Vaxasoftware</a>	<a href="#">Engineering Toolbox</a> <a href="#">Hyperphysics</a>	None	Not in Database

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