Analysis of Insulating Properties of Skin (Rodent)

Team Members: Caelen Nickel (Team Leader), Charles Maysack-Landry (Communicator)
Annika Syslack (BPAG), Tayler Carlson (BWIG), Caden Binger (BWIG), Bryan Heaton (BSAC)
Client: Dr. Caroline Alexander **Advisor:** Dr. Justin Williams

MOTIVATION

- Facilitate oncologist researches in quantifying thermal insulation of samples of rodent skin
- Currently, there two methods available to researchers that are not accurate and/or costly:
  - Infrared thermometer of thermal imaging camera (Figure 1)
  - Thermtest MP-1 device (Figure 2)

Figure 1: Commercially available Omega infrared thermometer [1].

Figure 2: Thermtest MP-1 device measurement platform [2].

Problem Statement

- There is not a cost effective, accurate device to measure the thermal conductance of rodent skin samples as required for oncology research.

BACKGROUND

- Skin is a complex system in its anatomy and physiological function, including heat regulation through dissipation.
  - Adipose tissue stores thermal energy close to the skin surface [3].
  - Lamellar bodies carry cargo necessary for maintaining homeostatic temperature [4].

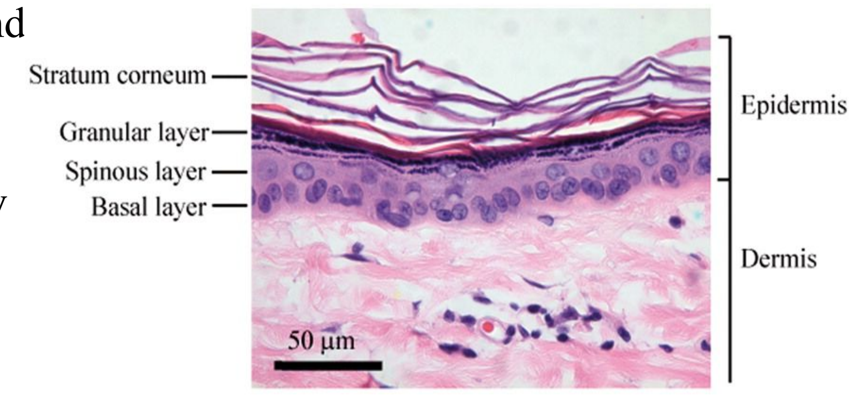

Figure 3: Side cut microscopy of the layering in skin [4].

- Heat transfer is closely related to metabolism, the net sum of reactions that provide the body with energy and consume it.
- Increased heat dissipation through less insulative skin can increase metabolic rate [5].
- Evaporative cooling causes inaccuracies in non-contact temperature measurement.
  - Water in skin is heated and evaporates, releasing thermal energy.
  - Direct contact with skin prevents this evaporation from occurring.

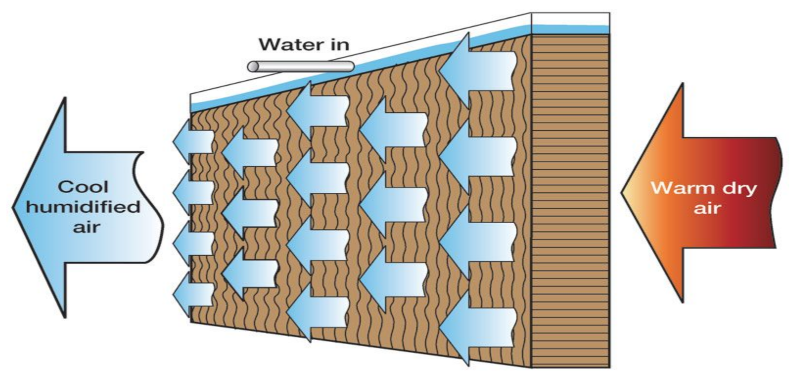

Figure 4: Illustration of evaporative cooling [6]

DESIGN CRITERIA

- **The device must:**
  - Heat skin sample with 34℃ ± 0.5℃ pulses
  - Accurately measure temperature within 0.1℃
  - Accommodate samples of ex-vivo rodent skin 4x2 cm and 50-100 µm thick
  - Measure heat transfer without being influenced by evaporative cooling
  - Display temperature data graphically in relation to time
  - Avoid damage to skin samples and withstand intended use

FINAL DESIGN

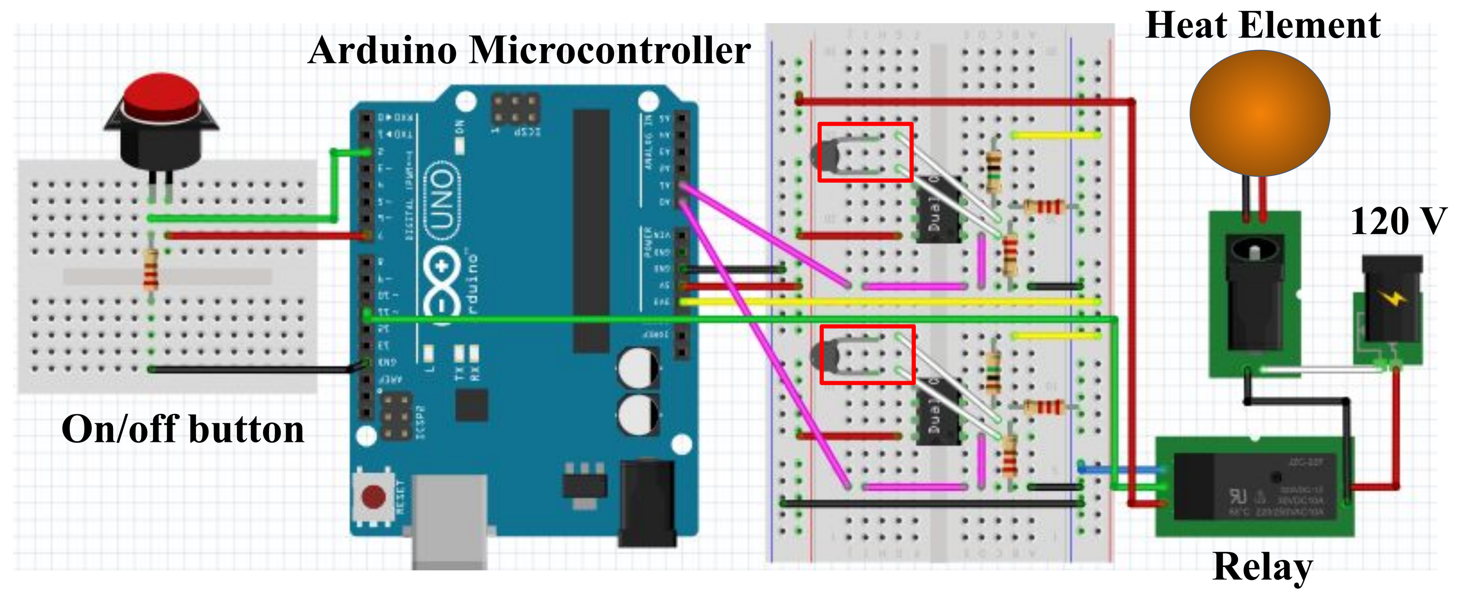

Figure 5: Custom Fritzing diagram of the circuit, showing an illustration of the schematic, connections, and components (thermistors on breadboard)

Final Design Features:

- Powered heating element provides 34℃ temperature to skin sample
- Two thermistors collect temperature data on either side of the sample
- Arduino and thermistor circuits calculate temperature
  - Heating element modulation
  - Data collection
- Arduino controls relay, allowing voltage to power heating element
- On/off button for device control

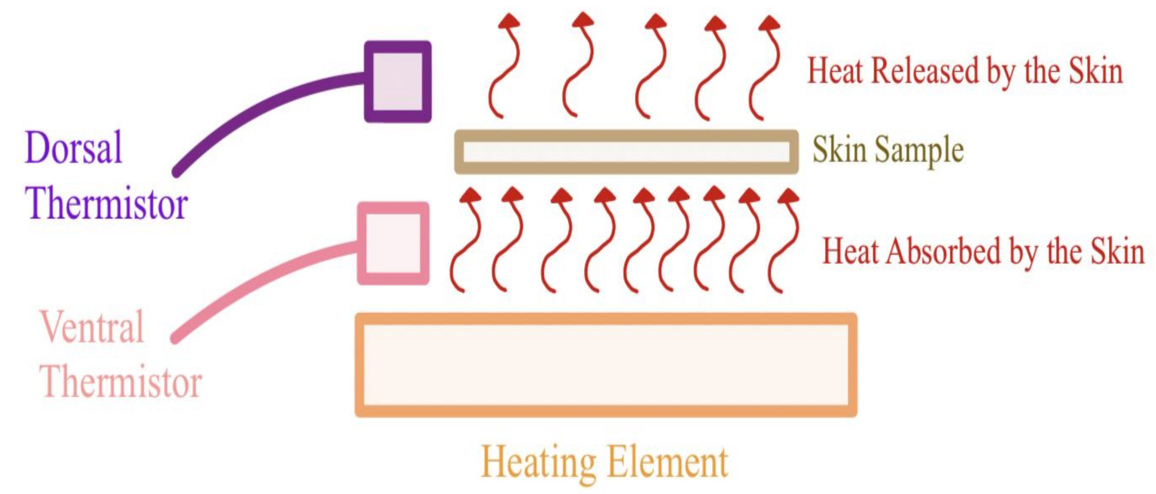

Figure 6: Overall design summary

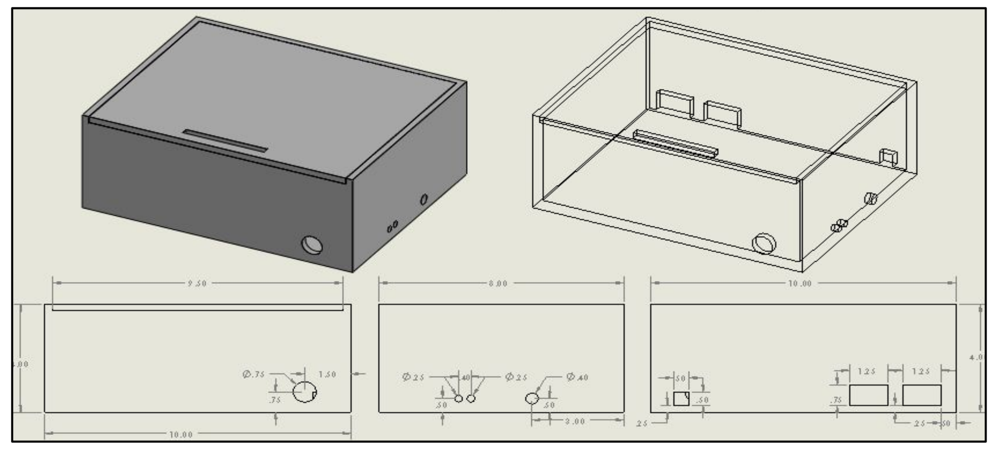

Figure 7: SOLIDWORKS drawing of the exterior box containing the circuit

TESTING & RESULTS

Heating Element

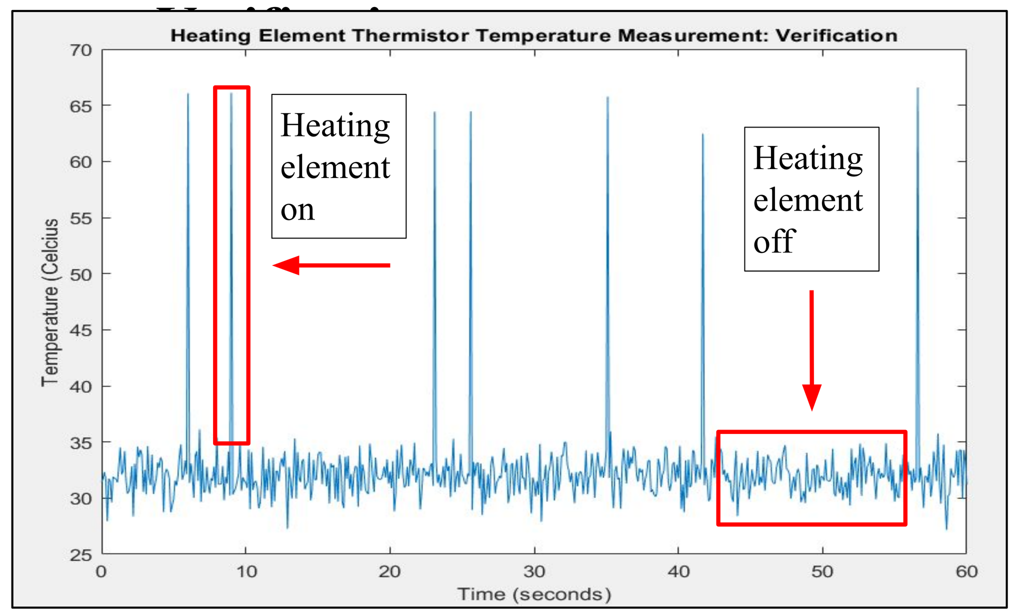

Figure 8: Graph showing the thermistor temperature reading of the heating element over time while running

Skin Temperature Test

- Skin temperature was measured using the thermistor and infrared thermometer, and a student t-test was conducted

Table 1: Means, standard deviations and p-value for 10 second temperature readings via thermistor and infrared

	Mean (℃)	Standard Deviation (℃)
Thermistor	34.91	0.3520
Infrared	33.2	0.2938
p value	1.24E-7 < α = 0.05	

Tegaderm® Layer Test

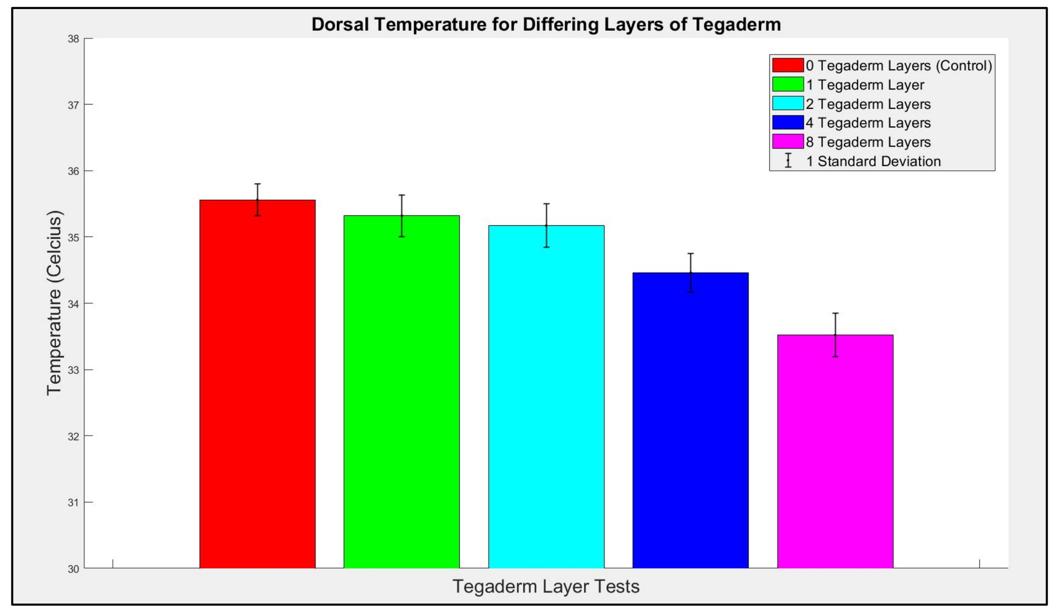

Figure 9: Graph comparing the thermistor temperature readings across 0, 1, 2, 4, and 8 layers of Tegaderm®

- To determine the sensitivity of the thermistor circuit, temperature measured across variable Tegaderm® layers
- A multiple comparison test was performed to evaluate

p value	1.00E-5 < ã = 0.01

- The p-values for both the Skin Temperature Test and Tegaderm® Layer Test are below respective α values
- Skin Temperature Test null hypothesis of no difference between temperature measurement methods; and Tegaderm® Layer Test null hypothesis of no difference in dorsal temperature between layers are both rejected.

DISCUSSION

Design Achievements

- The final device is sufficient in measuring the temperature on the dorsal surface of skin without accounting for evaporative cooling.
- Heating element verification testing showed that the skin sample is supplied with approximately 34℃ consistently on the ventral surface.
- Device is adequately sensitive in measuring the temperature through variable layers of Tegaderm® with recognizable difference, as shown in Figure 9.

Design Drawbacks

- Tape is required to ensure thermistor contact with skin sample.
- The heating element heats exceedingly fast, reaching temperatures of 70℃ before the sampling frequency of the Arduino allows a response.
- Breadboard connections and inexpensive components possess inaccuracies.
- Limited resolution of the Arduino and noise contribute to inconsistencies in temperature measurements, as shown in Figure 8.

FUTURE WORK

Design future work:

- Create a PCB (printed circuit board) of the device's circuit, as shown in Figure 10
  - Increase accuracy of connections and decrease footprint
- Incorporate a higher quality heating element
- Design a mechanism for applying the thermistors to skin sample and heating element instead of tape (Figure 11)

Figure 10: Visualization of an assembled PCB [7]

Testing future work:

- Repeat heating element verification with adjusted resolution and heating element
- Test against Thermtest MP-1 device
- Perform ergonomics testing with the final design for researcher evaluation
  - Quantify ease of use, other PDS criteria

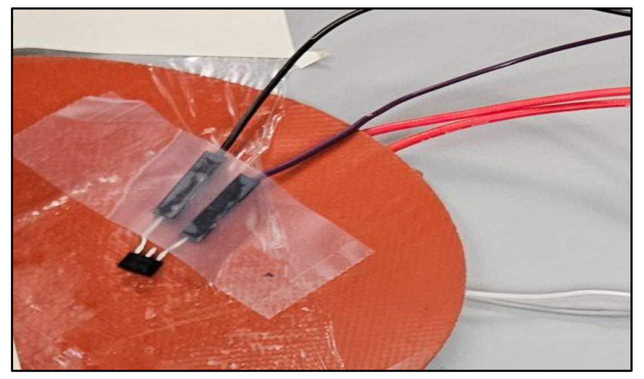

Figure 11: Thermistors taped to Tegaderm® and heating element

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