Lizard Energy Budget

Total Lizard Energy Budget

Evaporation

Incoming radiation

Outgoing radiation

$$M - \lambda E + Q_a - \varepsilon\sigma\left[T_b + 273.15 - I\left(M - \lambda E\right)\right]^4 - h_c\left[T_b - T_a - I\left(M - \lambda E\right)\right] = 0$$

Metabolism

Convection

Insulation effects

Can't solve analytically !!

Break up into separate pieces or functions:

$$M = 0.0258 e^{T_b/10}$$

$$\lambda E = \begin{cases} 0.27 & T_b \le 20 \\ 0.08 e^{0.0586 T_b} & 20 < T_b < 36 \\ 0.00297 e^{0.1516 T_b} & T_b \ge 36 \end{cases}$$

$$Q_{out} = \varepsilon\sigma\left[T_b + 273.15 - I\left(M - \lambda E\right)\right]^4$$

$$C = h_c\left[T_b - T_a - I\left(M - \lambda E\right)\right]$$

$$h_c = k_1\sqrt{\frac{V}{D}}$$

Combined in the root function:

$$M - \lambda E + Q_a - Q_{out} - C = 0$$

```
#include…

float f( float );
float fprime( float );

int main( void )
    {
    int i…
    float x1,…
    x1 =…

    for( i=0; i<20; i++ )
        {
        x2 = x1 - …
        if( fabs(x2-x1) < 1e-6 ) break;
        x1 = x2;
        }

    printf( “Results are…” );

    return 0;
}

float f( float x )
{
    return x * x – 5;
}

float fprime( float x )
{
    float h = 0.0001;
    return ( f(x+h) – f(x-h) ) / (2*h);
}
```

Global variables?

Put lizard functions in here!

```
M = …
E = …
Qout = …
hc = …
C = …
```

Now that budget program works…

Uses for Energy Budgets

Useful to calculate lizard body temperature, but also each budget term:

- Radiation in
- Radiation out
- Convection
- Evaporation
- Metabolism

How does environment affect lizard body T?

Why (what is cause)?

General Lessons from Organism Energy Budgets

Inputs $\rightarrow$ $Q_a + M = Q_{out} + C + \lambda E$ $\leftarrow$ Outputs

$$Q_{out} = \varepsilon\sigma\left[T_b + 273.15 - I\left(M - \lambda E\right)\right]^4$$

$$M = 0.0258 e^{T_b/10} \qquad \lambda E = ?e^{?T_b}$$

$$C = h_c\left[T_b - T_a - I\left(M - \lambda E\right)\right] \qquad h_c = k_1\sqrt{\frac{V}{D}}$$

1) Radiation incoming

Increased Qa means outgoing energy must balance – increased body T

$$Q_a\uparrow \rightarrow T_b\uparrow$$

$$Q_a + M = Q_{out} + C + \lambda E$$

$$Q_{out} = \varepsilon\sigma\left[T_b + 273.15 - I\left(M - \lambda E\right)\right]^4$$

$$M = 0.0258e^{T_b/10} \qquad \lambda E = ?e^{?T_b}$$

$$C = h_c\left[T_b - T_a - I\left(M - \lambda E\right)\right] \qquad h_c = k_1\sqrt{\frac{V}{D}}$$

2) Air temperature

$$T_a\uparrow \rightarrow T_b\uparrow$$

Convection acts to bring surface T closer to air T

$$C = h_c\left(T_r - T_a\right)$$

$$Q_a + M = Q_{out} + C + \lambda E$$

$$Q_{out} = \varepsilon\sigma\left[T_b + 273.15 - I\left(M - \lambda E\right)\right]^4$$

$$M = 0.0258e^{T_b/10} \qquad \lambda E = ?e^{?T_b}$$

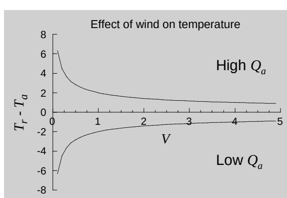
$$C = h_c\left[T_b - T_a - I\left(M - \lambda E\right)\right] \qquad h_c = k_1\sqrt{\frac{V}{D}}$$

3) Wind

$$V\uparrow \rightarrow h_c\uparrow \rightarrow C\uparrow$$

Convection acts to bring surface T closer to air T

$$C = h_c\left(T_r - T_a\right)$$



$$Q_a + M = Q_{out} + C + \lambda E$$

$$Q_{out} = \varepsilon\sigma\left[T_b + 273.15 - I\left(M - \lambda E\right)\right]^4$$

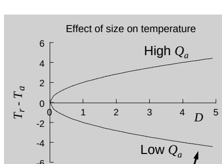
$$M = 0.0258e^{T_b/10} \qquad \lambda E = ?e^{?T_b}$$

$$C = h_c\left[T_b - T_a - I\left(M - \lambda E\right)\right] \qquad h_c = k_1\sqrt{\frac{V}{D}}$$

4) Organism size (D)

$$D\uparrow \rightarrow h_c\downarrow \rightarrow C\downarrow$$

$$C = h_c\left(T_r - T_a\right)$$



Large surfaces can form dew at night!

$$Q_a + M = Q_{out} + C + \lambda E$$

$$Q_{out} = \varepsilon\sigma\left[T_b + 273.15 - I\left(M - \lambda E\right)\right]^4$$

$$M = 0.0258e^{T_b/10} \qquad \lambda E = ?e^{?T_b}$$

$$C = h_c\left[T_b - T_a - I\left(M - \lambda E\right)\right] \qquad h_c = k_1\sqrt{\frac{V}{D}}$$

5) Insulation

Intuition - Greater insulation ($I\uparrow$) should increase body T

$$M - \lambda E = \frac{T_b - T_r}{I}$$

Cold day – E and M are very small, so insulation not very important.

*** Lizard Energy Budget ***
Enter Qa (W/m^2) : 600
Enter wind speed (m/s) : .5
Enter lizard size (m) : .01
Enter lizard insulation resistance : .02
Enter emissivity : .95
Enter air temperature : 5
Energy terms:
Qa=600.00
Qout=368.12
C=231.28
E=1.00
M=0.40
Lizard body temperature = 14.360

14.37 ºC for I = 0.002

*** Lizard Energy Budget ***
Enter Qa (W/m^2) : 800
Enter wind speed (m/s) : 1.0
Enter lizard size (m) : 0.01
Enter lizard insulation resistance : 0.002
Enter emissivity : 0.95
Enter air temperature : 40
Energy terms:
Qa=800.00
Qout=563.68
C=233.45
E=13.10
M=10.23
Lizard body temperature = 46.683

Hot day, E and M are still fairly small

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5) Insulation – cont'd

Insulation only matters for organisms that have a high metabolic rate??

If $M >> \lambda E$, an increase in I should increase $T_b - T_r$ when the air is cold.

$$M - \lambda E = \frac{T_b - T_r}{I}$$

What about on a very hot day – Can you stay cool with lots of insulation??

What about heavily insulated polar bears – Why is their fur white??

T_r only below T_a at night? …Needles story…