

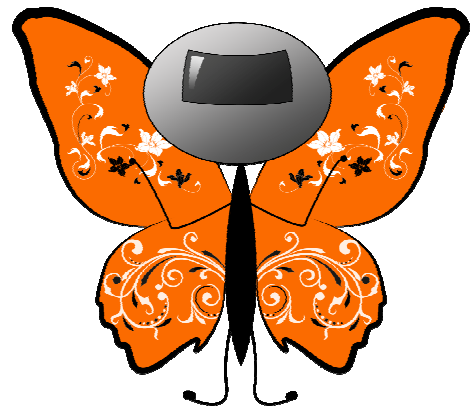
Butterflies in Space

Research Project
11th D class

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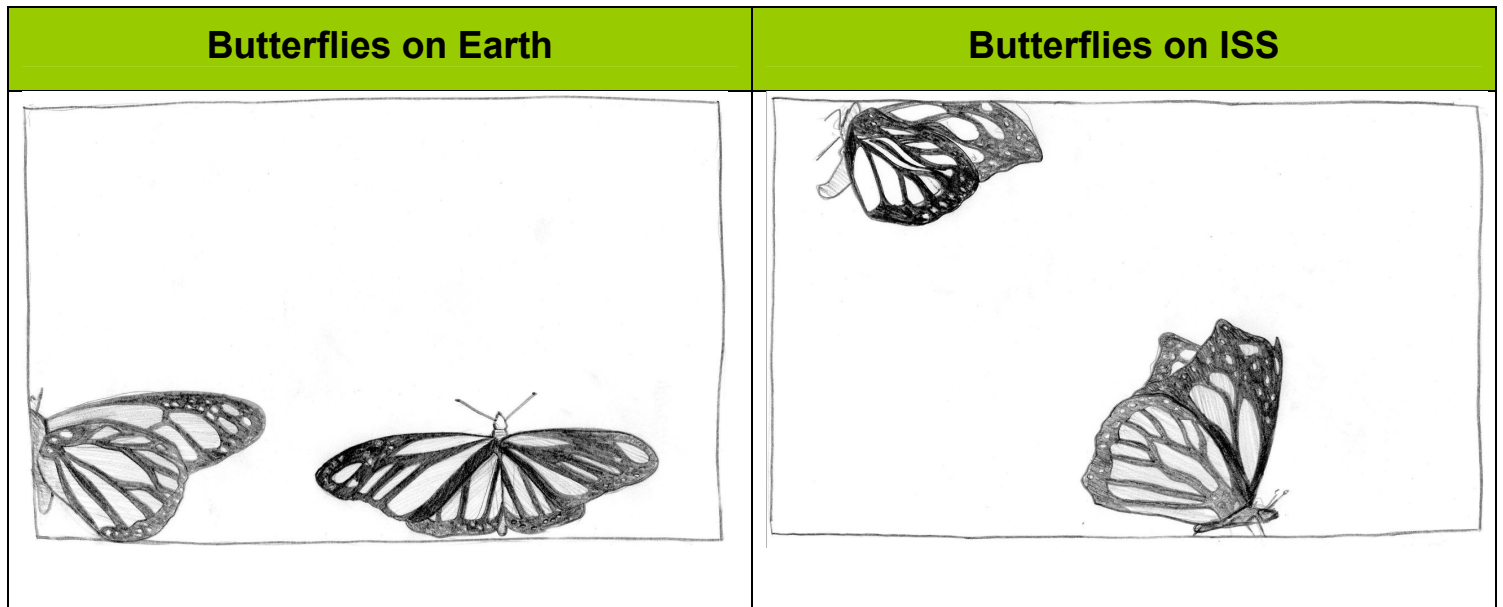
Experimental data

I. Measurements

1. Methods applied:


- we took pictures of our butterflies everyday at 11 a.m. and compared them with the images from ISS;
- we made sketches of the butterflies to compare their physical features;
- we monitored the pressure and temperature levels using the same barometer and thermometer each day, to make sure there were no fluctuations;
- we measured the dimensions of the larvae and butterflies, using a ruler;
- we used mathematical equations to interpret the obtained data.






2. Sketches









3. Data tables:

a) On Earth:

Day	Size (cm)	Temperature (C)	Pressure (mbarr)	Observations	Photo
11 (16.03.2010)	3.8	22	1017	First day of measurements. Due to unfavorable weather conditions, we only have 4 larvae, instead of 5.	

<p>12 (17.03.2010)</p>	<p>4</p>	<p>23</p>	<p>1017</p>	<p>The larvae have accommodated with the new environment and start to build a wire network.</p>	
<p>13 (18.03.2010)</p>	<p>4.4</p>	<p>23</p>	<p>1017</p>	<p>The network becomes more complex; the food level decreases.</p>	
<p>14 (19.03.2010)</p>	<p>4.4</p>	<p>23</p>	<p>1017</p>	<p>The necessary amount of food has been consumed; the larvae become inactive.</p>	
<p>15 (20.03.2010)</p>	<p>4.4</p>	<p>23</p>	<p>1017</p>	<p>The larvae used the network to attach to the lid; they gradually come into the "J" position.</p>	
<p>16 (21.03.2010)</p>	<p>4.4</p>	<p>23</p>	<p>1017</p>	<p>The larvae are moved to a bigger habitat.</p>	

b) On ISS:

Day	Size (cm)	Temperature (C)	Pressure (mbarr)	Photo
10 (18.11.2009)	1.7	25	1013,25	 Center food slot = 3.3 cm x 1.0 cm Date: 2009-11-18 23:06:52
11 (19.11.2009)	2.2	25	1013,25	 Center food slot = 3.3 cm x 1.0 cm Date: 2009-11-19 23:35:04
12 (20.11.2009)	2.8	25	1013,25	 Center food slot = 3.3 cm x 1.0 cm Date: 2009-11-20 23:34:53
13 (22.11.2009)	3.3	25	1013,25	 Center food slot = 3.3 cm x 1.0 cm Date: 2009-11-21 23:05:11
14 (23.11.2009)	3.5	25	1013,25	 Center food slot = 3.3 cm x 1.0 cm Date: 2009-11-23 23:20:28
15 (24.11.2009)	3.6	25	1013,25	 Center food slot = 3.3 cm x 1.0 cm Date: 2009-11-23 23:05:51

4. Data processing

a) Habitat conditions

We registered only minor fluctuations of pressure and temperature in our research laboratory. Moreover, the measured values were in the accepted limits, similar to those on ISS. Thus, these conditions shouldn't have a significant influence on the butterflies' behavior and development.

b) Butterfly dimensions:

The graph in *Figure 1* illustrates a comparison between the dimensions of the larvae on Earth and those on ISS.

We noticed that caterpillars on ISS are smaller than ours, but they keep growing in length for all 6 days, while the ones we measured in the laboratory stopped growing in length after the first 3 days of measuring.

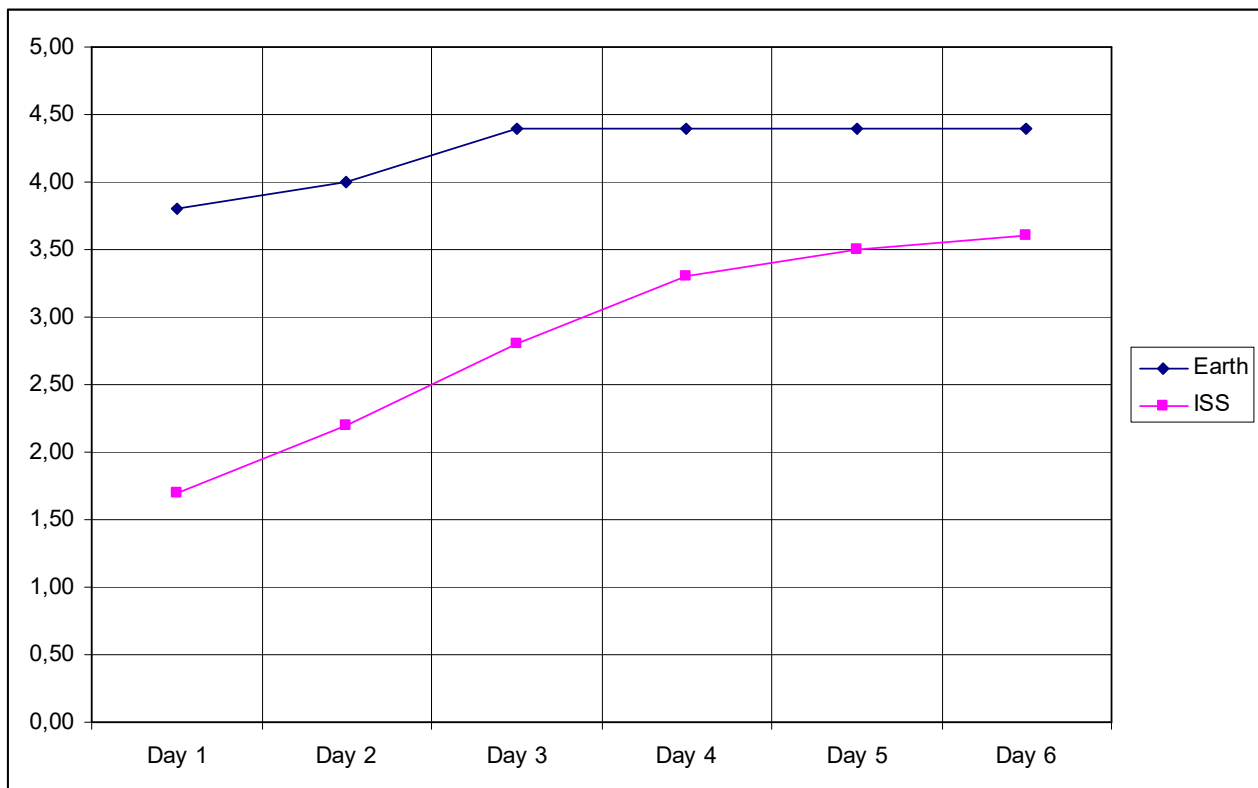


Figure 1: Representation of daily dimensions for the larvae on Earth and on ISS

c) Growth rate:

We calculated the growth rate of the caterpillars as the arithmetic mean of the slopes of the lines forming the graph:

- Growth rate for our research butterflies: $(0.2+0.4+0+0+0)/6 = \mathbf{0.12}$;
- Growth rate for the butterflies on ISS: $(0.5+0.6+0.5+0.2+0.1) = \mathbf{0.38}$.

Notice the value is greater for the “butterflynaughts”.

c) Life cycle:

	Research butterflies	Butterflynaughts	Vanesa Cardui (general information)
Caterpillar	13 days	6-7 days	7-11 days
Chrysalis	11 days	7-8 days	7-11 days

Notice the butterflies in space evolve faster than the ones raised in our laboratory. [6]

II. Observations

a) On ISS:

We analyzed the available footage which captured the butterflies’ behavior. The moments recorded were from two consecutive days:

- 3 December 2009: there is only one butterfly emerged from the pupa;
- 4 December 2009: a second butterfly emerges from the pupa.

Here are our observations below:

12/03/09:

- the butterfly is floating aimlessly inside the box;

- it does some short, sudden moves trying to control its direction, but doesn’t seem to have a target; it’s moving its body rather than its wings;

12/04/09:

- the elder butterfly (1 day old) is moving very slowly;
- the newly-emerged butterfly looks disorientated and is desperately trying to stretch its wings;

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- the butterflies have problems maintaining their balance;
 - they are trying to attach themselves to the walls (not flying aimlessly anymore);
 - there are some flying attempts, but they can't control their speed and they keep hitting the walls;
 - while one of the butterflies is more active (uses its wings often and tries to fly), the other one is static and moves using mainly its limbs.

b) On Earth:

On Earth, *Vanessa Cardui* butterflies fly in a smooth, balanced way with a constant beat stroke of about 20 Hz assuring enough lift for a straight, horizontal flight. The monarch butterflies are capable of flying many miles in their lengthy migrations over North America and some of them even cross parts of the Atlantic. The length of these journeys exceeds the normal lifespan of most monarchs and only the fourth generation of butterflies completes them [1],[2],[3].

III. Error sources

While analyzing and interpreting our data, we must also consider possible error sources:

- Imperfections of the instruments used (rulers, thermometers etc.);
- Gradients of temperature and pressure in our laboratory;
- Disturbance of the butterflies' activities by human presence (although we tried not to influence them in any way);
- Approximation of the results;
- Small number of studied butterflies.



Conclusions

Considering the small number of Painted Lady butterflies studied in our laboratory, a generalization would be somewhat inappropriate. We tried, wherever possible, to compare our data with general characteristics for the *Vanessa Cardui* specie and, unfortunately, we noticed several differences. However, some conclusions can still be inferred.

We've noted our observations below, for each of the proposed research questions:

1. Do the butterflies go through the metamorphosis stages normally?

The butterflies on ISS seem to evolve slightly faster than the ones on Earth. Also, while in their caterpillar stage, they continue to grow for the entire period, while our research butterflies stagnate to a constant value after the third day.

2. Does microgravity affect their movement pattern?

Monarchs on ISS exhibit fairly modest flying attempts. Immediately after emerging from the pupa and drying their wings, the *Vanessa Cardui* butterflies try to use their wings for movement. The videos recorded on ISS show that initially they are disoriented and cannot control their speed properly. However, they shortly adapt their behavior to the environment and omit using their wings extensively. Also, after periods of merely floating in microgravity, the butterflies seem to attempt to control their direction with sudden twists of the abdomen.

On the other hand, the butterflies in our laboratory seemed disoriented immediately after emerging, but this was only a temporary state, as they soon started enhancing their flying skills. Also, Earth-raised butterflies seemed to be more active than the ISS-raised ones.

In general, *Vanessa Cardui* butterflies on Earth fly in a balanced manner, a sign that they evolved on the planet from generation to generation. They migrate over large distances in different periods of the year, flying hundreds of miles in a controlled manner, which the butterflies on ISS would certainly not be capable of [4],[5].

3. Do they have differences in structure or appearance?

Our initial hypothesis was that the butterflies living in microgravity would be larger than the ones on Earth. This proved to be wrong. On the contrary, the “butterflynaughts” are smaller in size than our butterflies – the caterpillars differ with over 1 cm in length. We believe that butterflies born and raised in microgravity might grow to be larger because their cells would expand constantly and there wouldn’t be any accommodation period.

However, the wingspan of the butterflynaughts is of approximately 5.5 cm, slightly larger than the average values for *Vanessa Cardui*. [1]

Also, another difference we observed is that the wings of the “butterflynaughts” remain slightly wrinkled, probably due to the effect of microgravity.



Questions and Proposals for Further Study

- How would butterflies born on the ISS behave on Earth? Would they survive?
- Would butterflies born on ISS, in microgravity conditions, grow bigger than the current “butterflynaughts”?
- Have any changes been observed in the behavior of the butterflies after returning from the ISS? If so, are the effects similar to those experienced by human astronauts? (e.g. dizziness etc)
- Would a larger box (and perhaps fitted with a cleaning system to eliminate the frass and food residue) allow a better study of the flight patterns? Perhaps a larger box would let the butterflies actually fly, not just float in microgravity?



Acknowledgements

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Also, many thanks to Tim and Margaret Jenkins, from Gribblybugs, for sending us the caterpillars all the way from Coventry, England, despite the harsh weather conditions. [7]



Bibliography and Resources

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