Fractal dimension in butterflies' wings: a novel approach to understand phylogenetic relationship

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Introduction

The geometrical complexity in the wings of various, taxonomically different butterflies can help us to understand the possible evolutionary relationship by analyzing their fractal dimensions. The fractal dimension of the wing patterns of the Monarch and its mimicry species Viceroy has been well documented before however the fractal dimension of wing patterns of the Black Swallowtail and Pipevine Swallowtail remains unknown. Here, we investigate the wing patterns of local butterflies and their mimic species: The Monarch and it's mimic the Viceroy, and the Black Swallowtail and it's mimic the Pipevine Swallowtail. Using MatLab, the complexity of their wing patterns is quantified by their fractional dimension and then calculated through the box-counting method. Preliminary results indicate the fractal dimension of the wing patterns of the Monarch and its mimicry species Viceroy are closely related. This can give us some insight into the evolutionary relationship of the Monarch and its mimicry species Viceroy and can help us to determine the phylogenetic relationship with the less investigated species Black Swallowtail and its mimic the Pipevine Swallowtail by comparing their fractal dimensions.

A.

B.

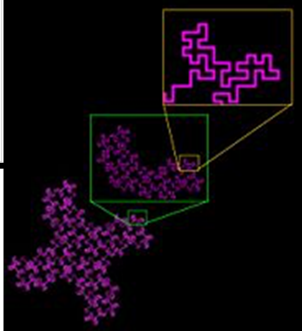
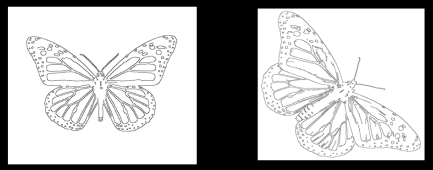


Figure 1. Phenotypic variation among species and their mimicry.
B) Fractal dimension quantification using box-count analysis.

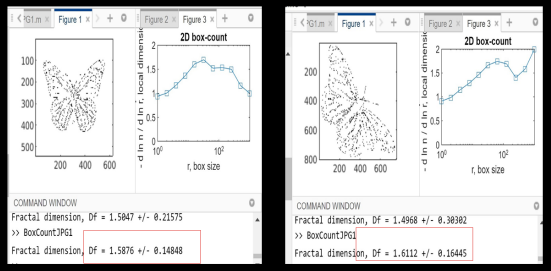
Methods

1. Photographs of the butterfly species were collected from the interned using a solid colored background .

2. The photographs were converted into line pictures using Picture Stencil Maker Software.



3. The line pictures were incorporated into MatLab to find the fractal dimension of the wing patterns of the desired species.



4. The average for the fractional dimension values and their errors were omputed for each species.

5. Confidence interval values were calculated and compared among the pecies and their mimicry.

Results

Monarch			Viceroy		
M1	1.6684	0.080218	V1	1.6529	0.12329
M2	1.5786	0.16757	V2	1.6138	0.20952
M3	1.5749	0.15539	V3	1.6132	0.16959
M4	1.5818	0.16066	V4	1.4963	0.20816
M5	1.5525	0.16289	V5	1.6571	0.066
M6	1.5516	0.19502	V6	1.4968	0.19523
M7	1.5047	0.21575	V7	1.5359	0.17949
M8	1.5876	0.14848	V8	1.7164	0.084604
M9	1.7192	0.16953	V9	1.5156	0.19298
M10	1.7071	0.17922	V10	1.7185	0.18508
AVERAGE	1.60264	0.163473	AVERAGE	1.60165	0.161394

Black Swallowtail			Pipevine Swallowtail		
BS1	1.5629	0.10165	PS1	1.5626	0.13598
BS2	1.5222	0.16575	PS2	1.5482	0.10662
BS3	1.5408	0.21726	PS3	1.5397	0.21252
BS4	1.5897	0.15567	PS4	1.5399	0.13911
BS5			PS5	1.6154	0.11157
BS6			PS6	1.4259	0.27339
BS7			PS7	1.6724	0.20408
BS8			PS8	1.7295	0.21118
BS9			PS9	1.5143	0.10234
BS10			PS10	1.4545	0.14463
AVERAGE	1.5539	0.10165	AVERAGE	1.56024	0.164142

Figure 2. Computed average Fractal Dimension values for the butterfly species.

Butterfly Specie(s)	FD Confidence Interval
Monarch	(1.439167, 1.766113)
Viceroy	(1.440256, 1.763044)
Black Swallowtail	(1.45225, 1.65555)
Pipevine Swallowtail	(1.396098, 1.724382)

Figure 3. Fractal Dimensions Confidence Intervals to compare the relatedness of the butterfly speciea and their mimicry

Conclusions

- The FD CI of the wing patterns of the Monarch and its mimicry Viceroy overlaps which indicates that they are closely related.
- The FD CI of the Black Swallowtail and it's mimcry the Pipevine Swallowtail overlaps which suggests they are closely related. However, more data should be analyzed for the Black Swallowtail species in order for the results to be consistent.
- Experiment has to be repeated for the results to be significant.

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