

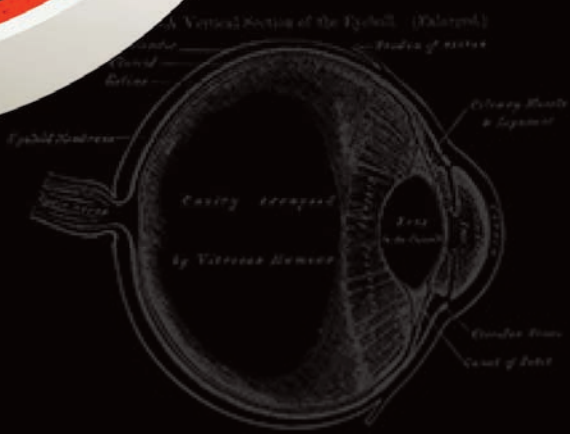
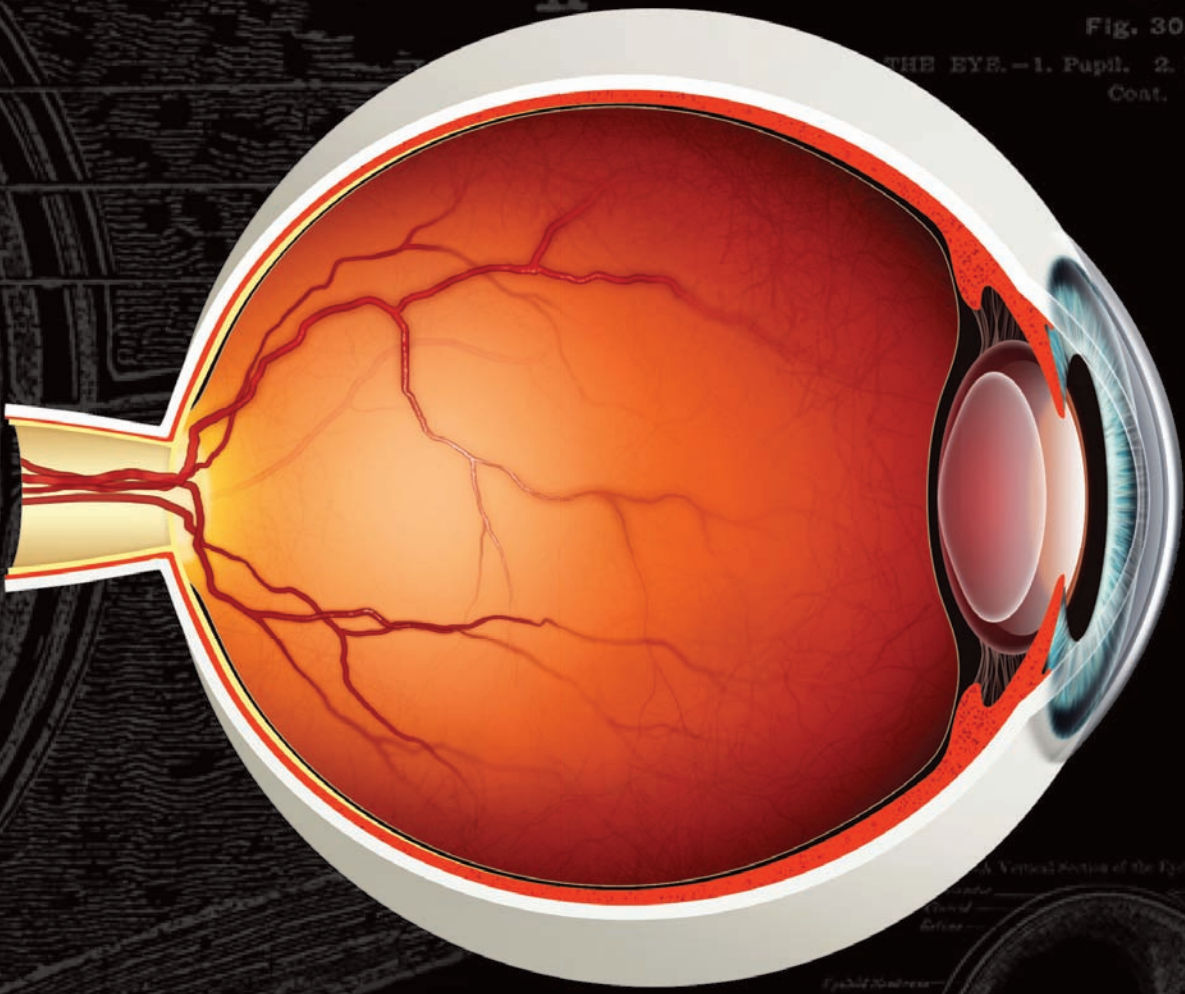
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CREATION RESEARCH SOCIETY QUARTERLY



Fig. 30.

THE EYE. — 1. Pupil. 2. Iris. 3. Sclerotic Coat.



nea. B, Watery humor. C,
coat. K, Retina. L, Glassy

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For in six days the Lord made heaven and earth, the sea, and all that in them is, and rested on the seventh. —Exodus 20:11

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Five Features Correlate with Seed Weight in Yuccas to Support a Seed-Dispersal Hypothesis

George F. Howe*

Abstract

Morphological observations were made on fruits, seeds, stems, leaves, and flowers of 13 species of *Yucca* at various locations in California, Arizona, and eastward. The dates of flowering, fruit production, and fruit fall (or fruit persistence) were recorded. Seed samples for 12 of the 13 species were weighed, and fell into two different weight classes: light and heavy. It was observed that the species producing light seeds had a suite of five other correlated morphological characteristics. Conversely, most of the heavy-seeded yucca species had five different or contrasting features. Neither the seed weight classes nor their systematic correlation with the other five traits were covered in the *Yucca* literature consulted. Seeds of 14 additional *Yucca* species and one *Yucca* subspecies, taxa that were unavailable during the field studies, were commercially available from seed suppliers. It was possible to determine from the literature which of these 14 species possessed dehiscent pods, one of the attributes correlating with light seeds; and which ones produced indehiscent pods—the contrasting feature regularly associating with heavy seeds. The weights of the purchased seeds were consistent with the predictions that: (1) seeds from plants known to possess dehiscent pods would be light, and (2) the seeds from plants having indehiscent fruits would be relatively heavy. The few exceptions to other correlated features are listed and analyzed. It is proposed that the five features correlating with light seeds aid in transport of the seeds by wind. It is further hypothesized that the five contrasting attributes, which are usually present in heavy-seeded yuccas, foster seed dispersal by animals. These two hypotheses find support in the present data. Several additional morphological traits were analyzed and appear to be unrelated to seed dispersal or to phylogeny, posing a problem for neo-Darwinian macroevolution. The yucca correlations support a non-evolutionary origins model for *Yucca* species. Based on these data, further predictions are made, including the prediction that the correlations of seed weight with other features will also exist in the species and subspecies of *Yucca* not yet analyzed. Other possible avenues for future yucca research are enumerated.

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Introduction

The genus *Yucca* is comprised of several dozen species. In my original yucca paper (Howe, 1986), I used numerical taxonomy to show patterns of similarity among nine western yucca species. Based on that analysis, some morphological correlations became obvious. The deciduous pod was tied to three other features—pod indehiscence, non-erect fruit, and relatively short inflorescences (see Appendix 1). Persistent pods, to the contrary, were found to relate to fruits that dehisce, pods that stand erect, and inflorescences that are long. Thus there are six morphological correlations reported here—the original four plus two others: seed weight and ovary wall thickness.

The Creation-minded reader will find that a divine plan for seed dispersal in the genus *Yucca* becomes apparent. The details of *Yucca* seed weight, and other correlated characteristics, are fully consistent with the Creator's intelligent activity. Furthermore, these data cannot be readily explained by a coherent naturalistic scheme of origins.

Methods

The original field research, done in the western United States (Howe 1986), has been expanded here to cover two other western species, *Y. schottii* and *Y. arizonica*, for a total of nine western yuccas, as well as four other *Yucca* species eastward. Measurements were made in the field on these nine western and four other species, 13 total (see Tables 1-4). Records were kept on the locations of *Yucca* plants being studied and the nearby vegetation—Tables 6 and 7.

During the 2003 flowering period, certain individual *Yucca* plants in California and Arizona were chosen for repeated visitation from 2003 to 2007 in order to collect detailed information on plant morphology and on the phenology of such events as flowering, fruit development, fruit ripening, seed dispersal, and

the abscission or persistence of the ripe pods. The other yucca localities outside of California and Arizona were visited only once or, in some cases, twice.

Small quantities of seed from 11 *Yucca* species studied in the field (nine from the west and two from the east) were secured. The average weight per seed was determined for them by weighing all the seeds and dividing by the seed number (Table 1). Also, packets of seeds were ordered from several suppliers for the species not studied in the field, for some species that were not producing seeds at the time(s) of my visitation and as a check on some of the field species that did yield seeds (Tables 4 and 5). In Tables 4 and 5, each seed was weighed individually, allowing computation of the mean weight per seed and the standard deviation. The differences between the mean seed weights of what can be called the “lightest of the heavy-seeded species” (*Y. entlichiana*) and the “heaviest of the light-seeded species” (*Y. peninsularis*) could then be evaluated by computing and comparing the standard errors of the means.

Results

Seed Weight

Weights of seeds I collected for 11 of the 13 *Yucca* species studied in the field are reported in Table 1, along with the weight of commercially available seeds of *Y. torreyi* (because no seeds for *Y. torreyi* were present in the field). The tables include no seed weight data for *Y. gloriosa* (one of those species studied in the field), because pods were not present and seeds were unavailable from nursery catalogues. Weights for purchased seeds of some of these same 11 *Yucca* species of Table 1 are also found in Table 4.

Seeds of 14 other *Yucca* species and one *Yucca* subspecies, none of which were part of the field research, were later purchased and weighed (See Table 5). Thus, this paper contains weights for

26 of the 49 total species of *Yucca* and one of the 24 subspecies, as recognized by Hochstätter (2004). I could find no other published records of seed weights for yucca species in the literature. Seeds of 23 more yucca species and 23 subspecies need yet to be weighed.

Whether from the field or from seed suppliers, all of the *Yucca* seeds consistently fell into two general weight classes with no overlap: 14 taxa (13 species and one subspecies) possessed light seeds, whereas 13 species possessed distinctly heavier seeds (Tables 1, 4, and 5). The mean for all the averages of heavy-seeded yucca species ($n=14$ species) was 89 mg (S.D. = ± 38 ; S.E. = ± 10.30). The mean of average weights for all light-seeded yuccas ($n=13$ species) was 12 mg (S.D. = ± 5.9 ; S.E. = ± 1.64). These sample means for the heavy-seeded and the light-seeded species are significantly different from each other.

To illustrate the extreme weight differences involved between the heavy and the light seeds, *Y. schottii* contained the heaviest seeds in the “heavy-seeded” group at 175 mg average (Table 1), while the lightest of all the light seeds were those of *Y. pallida*, weighing 4 mg per seed average (Table 5); almost 44 times lighter than seeds of *Y. schottii*. The “gulf” separating the average seed weights of light-seeded yucca species from the heavy-seeded ones was typically quite large, as in the case of *Y. harima-nae* (a light-seeded species) having seeds weighing only 13 mg compared to the heavy-seeded *Y. periculosa*, having an average seed weight of 103 mg, about eight times heavier (Table 5).

The closest that the average seed weight of any heavy-seed species came to the weight of a light-seeded yucca was *Y. entlichiana* (the “lightest of the heavy-seeded yuccas”) at 39 mg average (S.D. = ± 12.7 ; S.E. = ± 1.13). *Y. peninsularis* was the “heaviest of the light-seeded group,” at 23 mg average seed weight (S.D. = ± 6.24 ; S.E. = ± 1.30 ; see Table 5 and Figure 1). Even in the

Table 1. Correlated Seed-Dispersal Features in 13 Species of *Yucca*.

<i>Yucca</i> species	Average Seed Weight Milligrams (mg)	(+) = Ripe Pods Adherent (-) = Ripe Pods Deciduous	(+) = Ripe Pods Dehiscent (-) = Pods Indehiscent	(+) = Ripe Pod Walls Thin (-) = Pod Walls Thick, Fleshy or Dry	(+) = Pods Usually Erect (-) = Pods Not All Erect
Light-Seeded					
1. <i>angustissima</i>	22 n=10	+	+	+	+
2. <i>elata</i>	19 n=31	+	+	+	+
3. <i>filamentosa</i>	9 n=10	+	+	+	+
4. <i>glauca</i>	19 n=10	+	+	+	+
5. <i>whipplei</i>	13 n=20	+	+	+	+
Heavy-Seeded					
6. <i>aloifolia</i>	51 n=20	-	-	-	-
7. <i>arizonica</i>	159 n=30	-	-	-	-
8. <i>baccata</i>	171 n=40	-	-	-	-
9. <i>brevifolia</i>	78 n=37	-	-	-	-
10. <i>schottii</i>	175 n=10	-	-	-	-
11. <i>shidigera</i>	83 n=10	-	-	-	-
12. <i>torreyi</i>	94 n=26	-	- ^a	- ^a	- ^a
Possibly Heavy-Seeded					
13. <i>gloriosa</i>	? ^b	? ^b	- ^a	- ^a	- ^a

^a. This information is from the literature.

^b. Information unavailable in my field or literature work.

case of this extreme example, the heavy seeds were still about 1.3 times heavier than the light seeds, and their sample means differed significantly from each other. In all other comparisons be-

tween light-seeded and heavy-seeded species, the weight separations were even much greater than this distinct separation between *Y. entlichiana* and *Y. peninsularis*.

Five Traits Found Correlated with Light Seed Weight

The five light-seeded *Yucca* species of the field research (*Yuccas angustissima*, *elata*, *filamentosa*, *glauca*, and *whipplei*)

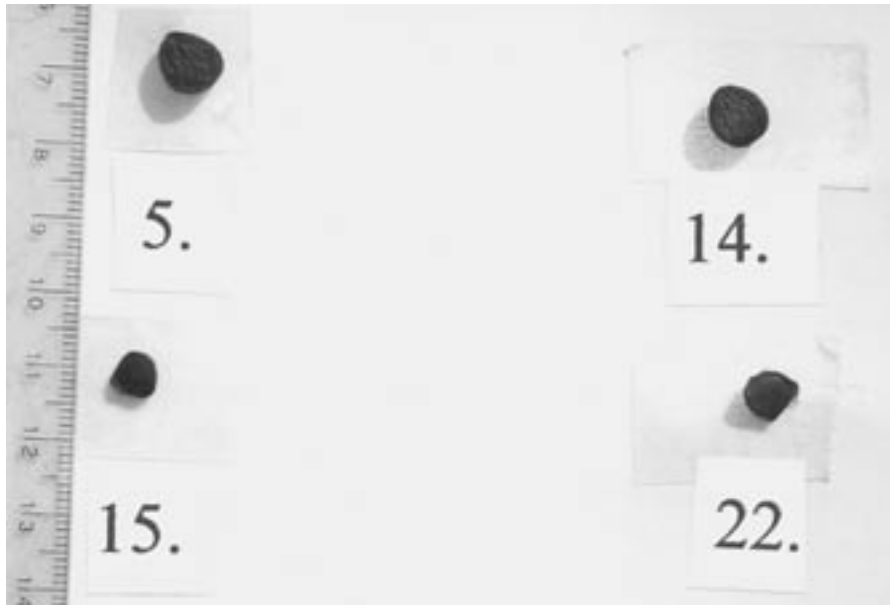


Figure 1. Seeds of four *Yucca* species. Number five is a seed of *Y. arizonica*, a species having heavy seeds (159 mg average) and indehiscent fruit. Seed number 14 is from *Y. australis*, which also produces heavy seeds (125 mg average) and pods that are indehiscent. Number 15 is a seed of *Y. entlichiana*, another heavy-seed indehiscent yucca. *Y. entlichiana* has the lightest seeds among all the heavy-seeded yuccas I weighed—39 mg average. Seed 22 is from *Y. peninsularis*, which has light seeds. These light seeds of *Y. peninsularis*, however, are the heaviest seeds among the light-seeded, dehiscent yuccas—22 mg average. It was one of the yucca seed-lots that I purchased and then weighed after making weight predictions. A clear centimeter-millimeter ruler can be seen far left.



Figure 2. A capsular (dehiscent) fruit of *Y. angustissima*, showing erect pod stature and dehiscence, both of which are characteristics of light-seeded species. A hole in the fruit wall made by an emerging yucca moth is visible, lower right. The long split at center is septical, and the shorter suture line at the right demonstrates loculicidal dehiscence—both of which can occur on the same pod in various yucca species.

each possessed these five characteristics in addition to light seeds:

1. Pods of the light-seeded *Yuccas* are dehiscent (Figures 2 and 3). All of the other 10 light-seeded taxa (Table 5) among the purchased seeds are also reported to have dehiscent pods (Hochstätter, 2000, 2002, and 2004).
2. The fruits of all five light-seeded species remain attached to the flower stalk (Figure 4 and Table 1), thus being “persistent.” (This does not mean that all the pods remain permanently attached. Various fruit do fall over a period of weeks, but numerous pods persist, continuing to shed seeds.)
3. Ovary walls are thin and dry upon ripening, in all the light-seeded species (Figure 5 and Table 1).
4. Pods have an erect, upright stance in the light-seeded species (Figures 2, 4, and Table 1).
5. *Yuccas* having light seeds all possessed inflorescences that held the fruit well above the leaf crown (Figure 4 and Table 2). This clearance is accomplished by an inflorescence possessing an elongated scape (Figure 4) or by a fruit-bearing portion of the inflorescence that is long enough to hold most of the fruit above the crown.

The five light-seeded *Yuccas* (species 1–5, Table 2) have the inflorescence extending above the crown to an average height of 111 cm. In contrast, the eight heavy-seeded species (species 6–13, Table 2) have an average inflorescence height above crown of 41 cm, despite the exceptionally tall inflorescence of *Y. gloriosa*. Discussion of *Y. gloriosa* and other exceptions is presented below.

The scape in the light-seeded species (1–5 of Table 2) made up 50% of the total inflorescence length, while in the heavy-seeded *Yuccas* the scape composed only 25% of the inflorescence length (6–13 of Table 2). The longer scape positions pods containing light seeds well above the fruit crown.



Figure 3. Pods of three different *Yucca* species—two that favor seed distribution by wind (*Y. angustissima* and *Y. whipplei*), and one that favors seed distribution by animals (*Y. brevifolia*). From left to right they are *Y. angustissima* (a species with dehiscent pods), two pods of *Y. brevifolia* (note their indehiscence), and one pod at the right of *Y. whipplei*, which is another dehiscent species, like *Y. angustissima*. This *angustissima* fruit (left) demonstrates both loculicidal and septicidal dehiscence occurring in the same fruit—sutures occurring in the carpels and between the carpels. The *Y. brevifolia* pods (center) have thick, although dry, fruit walls. The *whipplei* fruit at far right has loculicidal dehiscence and light seeds.

Five Reverse Traits Often Found in Heavy-seeded *Yuccas*

Most of the *Yucca* species that had the heavier seeds also manifested a suite of five “reverse” anatomical traits when compared to the light-seeded yuccas.

1. Pods of the seven heavy-seeded species studied (species 6–12 of Table 1) were indehiscent (Figure 3).
2. Fruits of most of the heavy-seeded *Yucca* species fall off upon ripening. (While most of the fruit does fall, a few pods may persist for weeks.) Six of the seven heavy-seeded *Yuccas* had deciduous fruits (Figures 6 and 7). The fruits of *Yucca aloifolia* are an exception to be discussed separately.
3. Ovary walls of the heavy-seeded *Yuccas* are thick and in most cases rather fleshy when ripe (Figure 3 and Table 1).
4. Pods of the heavy-seeded *Yuccas* (Table 1) were positioned in various directions, not always upright (Figure 6).

Table 2. Correlated Inflorescence Characteristics in 13 Species of *Yucca*.

<i>Yucca</i> Species	Inflorescence Length (cm)	Scape Length (cm)	Distance Inflorescence Extends above Leaf Crown (cm)
Light-Seeded			
1. <i>angustissima</i>	117 n=10	51 n=18	90 n=8
2. <i>elata</i>	195 n=20	106 n=20	143 n=20
3. <i>filamentosa</i>	129 n=10	65 n=10	101 n=10
4. <i>glauca</i>	81 n=20	39 n=10	40 n=10
5. <i>whipplei</i>	231 n=14	118 n=16	181 n=16
Heavy-Seeded			
6. <i>aloifolia</i>	93 n=13	29 n=13	56 n=13
7. <i>arizonica</i>	106 n=21	23 n=30	67 n=20
8. <i>baccata</i>	46 n=12	11 n=10	6 n=13
9. <i>brevifolia</i>	37 n=12	0	14 n=21
10. <i>schottii</i>	87 n=13	10 n=11	10 n=11
11. <i>schidigera</i>	51 n=49	0	17 n=24
12. <i>torreyi</i>	113 n=10	57 n=10	52 n=8
Possibly Heavy-Seeded			
13. <i>gloriosa</i>	145 n=11	60 n=12	103 n=12

Table 3. Some Noncorrelated Features in the 13 *Yucca* Species Studied.

<i>Yucca</i> species	Leaf Margin	Leaf Length (cm)	Leaf Width (cm)	Typical Crown Height (cm)	Inflorescence r = raceme p = panicle
Light-Seeded					
1. <i>angustissima</i>	Fibrous	31 n=33	0.51 n=31	0a.	r
2. <i>elata</i>	Fibrous	45 n=21	0.75 n=20	110 n=20	p
3. <i>filamentosa</i>	Fibrous	52 n=13	2.6 n=13	0	p
4. <i>glauca</i>	Fibrous	52 n=13	0.75 n=12	0	p or r
5. <i>whipplei</i>	Serrated	70 n=10	2 n=10	0	p
Heavy-Seeded					
6. <i>aloifolia</i>	Serrated	49 n=15	4.4 n=15	102 n=5	p
7. <i>arizonica</i>	Fibrous	52 n=20	2.3 n=21	198 n=13	p
8. <i>baccata</i>	Fibrous	61 n=22	3.3 n=4	—	p ^b .
9. <i>brevifolia</i>	Serrated	25 n=62	1.5 n=52	505 n=21	p
10. <i>schottii</i>	Smooth	62 n=21	3.2 n=19	144 n=19	p
11. <i>shidigera</i>	Fibrous	56 n=28	4.0 n=21	147 n=20	p
12. <i>torreyi</i>	Fibrous	131 n=2	4.0 n=8	285 n=9	p ^d .
Possibly Heavy-Seeded					
13. <i>gloriosa</i>	Smooth ^c .	60 n=23	3.9 n=11	45 n=10	p

^a *Y. angustifolia* usually has no trunk, but in some populations there is a short trunk. This is also true for *Y. glauca*.

^b Stalk of *Y. baccata* usually procumbent or absent, but in certain locations there is a short upright stalk.

^d Taken from the literature.

^c Sometimes very young leaves of *Y. gloriosa* are slightly serrated on a temporary basis.

5. The height of inflorescences and the distance that ripe pods were held above the leaf crown

in heavy-seeded yuccas was on average smaller than in the light-seeded *Yucca* species (Figure

10). The average length of the entire inflorescence usually is shorter for the four species that have heavy seeds (77 cm) than for the light-seeded species (151 cm)—see Table 2. The distance that the inflorescence stands above the leaf crown and the average scape length are both shorter for heavy-seeded species, as pointed out earlier.

Purchased Seeds and Collected Seeds

Seed packets of eight *Yucca* species, seeds of which had likewise been secured in the field, were purchased and weighed in order to compare weights of field and purchased samples (Table 4). No major weight differences were found between the field seeds and purchased seeds (compare values of Table 1 with those of Table 4). These data demonstrate the consistency of average seed weights between various populations of a given *Yucca* species.

Verification of all Predicted Seed Weights for Purchased *Yucca* Seeds

Seeds of 15 *Yucca* taxa (14 species and one subspecies) not covered in the field studies were ordered from seed suppliers. Predictions were then made, and the purchased seeds were subsequently weighed. All the predictions were verified such that species known from the literature to produce dehiscent pods always had light seeds; and yuccas known to bear indehiscent pods all had heavy seeds (Table 5).

Several Other Morphological Traits—Largely Uncorrelated

Other morphological traits show few, if any, consistent correlations to the light-seeded species, the heavy-seeded category, or amongst themselves (Table 3). Fibrous, serrated, and smooth leaf margins (Figure 3) are found in various species with no consistent relation



Figure 4. *Y. elata* plants growing east of Sonoita, AZ in late winter, 2002. Two stems are bearing inflorescences with ripe pods attached—one along the fence and one nearly in the center. The stalk along the fence line manifests how these putatively wind-distributed seeds are held high above the level of the leaf crown (143 cm average for *Y. elata*). Note on those inflorescences how the long, slender scape (lower portion of the inflorescence) bears no fruit. Some of the fruit of 2001 have already fallen, but many remain on these inflorescences. The upright pod stance seen here and the persistence of fruit prepare light-seeded species using wind to distribute seed.

to seed weight or to the other traits so closely associated with seed weight. Likewise, long or short leaves; wide or narrow leaves; and short or long crown heights appear in both the light and heavy-seed-

ed groups with no regular relationship to the correlated features. (Note that crown height is a different characteristic than the height of the inflorescence, a trait already discussed.) Other traits showing

no consistent tie with seed weight are blue-green versus green leaf color, and mountain versus desert habitat preference (Tables 6 and 7).

Field Data for the *Yuccas* Studied

Tables 6 and 7 contain geographic, altitudinal, and vegetational details for most of the sites where a particular species of *Yucca* was observed. Annual observations are reported on both Tables 6 and 7 for events having a phenological periodicity, such as dates of flowering, fruit ripening, pod depletion (for most of the heavy-seeded species), and pod adherence (for the light-seeded *Yuccas*).

The light-seeded, non-deciduous fruits remained attached to the inflorescence for months after having undergone dehiscence (Table 6). Table 7 shows that pods of heavy-seeded species generally underwent abscission soon after ripening, with the exception of *Y. aloifolia*.

For each study site some remarks have been made concerning nearby vegetation. These comments are not intended to serve as an ecological report for those localities, but as an illustration of the general differences in the plants associated with the various *Yucca* species. Note that common names are usually used and generic names occasionally.

Discussion

Two Hypotheses about the Function of Seed Weight and Correlated Features

Based on these data, I hypothesize, first, that the presence of light seeds together with the traits occurring in conjunction with light seeds favor the distribution of seeds by wind. Light seeds are more buoyant, which is a definite advantage in wind transport. Lightness of seeds also conserves plant resources. I observed that wind does indeed carry the seeds of *Y. whipplei*, a light-seeded species, and I theorize that seeds of all

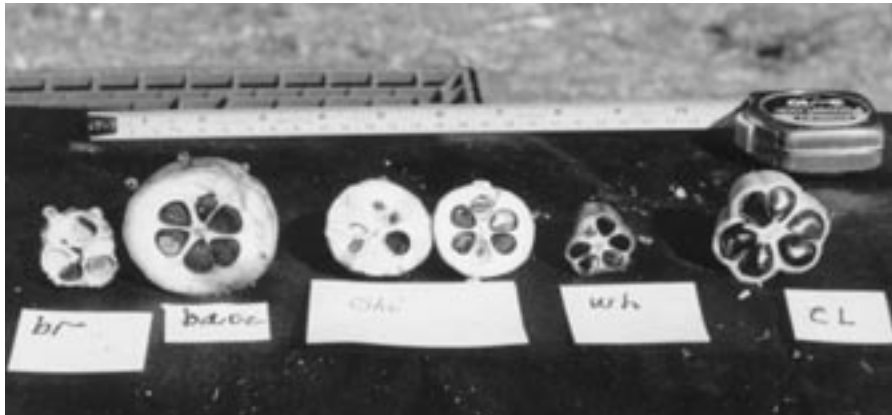


Figure 5. Fruit of five different *Yucca* pods cut in cross section. Beginning on the left, *Y. brevifolia* (br) is a heavy-seeded indehiscent yucca, which, nonetheless, has dry fruit walls. Next, *Y. baccata* (bacc) is a typical deciduous-fruited, indehiscent yucca, producing a thick (“baccate”) fruit wall, and heavy seeds. Next, the two fruit sections seen in the center are *Y. shidigera* (shi), another heavy-seeded plant having deciduous pods that are also indehiscent. *Y. shidigera* has a thick fleshy fruit wall that is a characteristic of many heavy-seeded yuccas—possibly designed as a reward to attract animals. *Y. whipplei* (wh, second from right) is a light-seeded yucca with thin fruit walls, as is also *Y. elata* (el) on the far right. The seeds of *elata* are large in terms of length and width, even though they are quite light in weight. These pods show the fact that most yuccas having wind-distributed seeds possess thin walled pods while most of those that presumably use animals for food transport have thick fruit walls.

the light-seeded *Yuccas* are distributed mostly by wind.

1. In addition to light seeds, it is important that the mature fruit split open to allow release and lateral dispersal of seeds. Indehiscence of pods would inhibit aerial transport of seeds.
2. In releasing these light seeds for air transport over time, it is likewise a distinct advantage that the fruit be non-deciduous, remaining attached to the inflorescence.
3. Seed transport by wind is favored for the fruit pods that have relatively thin ovary walls. This enables pods to split open readily while at the same time conserving plant resources.
4. Wind distribution of seeds is enhanced by the pods stand-

ing upright on the fruit stalk. If the pods were not positioned upright, most seeds would fall downward. With an erect fruit, however, ripe seeds remain stationed in the ovary that has undergone dehiscence until the wind carries most of them away from the parent plant.

5. The fact that most of the fruit in light-seeded species is perched significantly higher than the surrounding leaves enhances lateral seed transport by wind.

Second, I also propose the hypothesis that the heavy weight of certain yucca seeds is a planned inducement for animals such as pack rats to harvest and carry pieces of the yucca fruit with the seeds. While the fruits are being carried, and perhaps hidden, by animals, many seeds will be lost and

not eaten, providing for efficient seed dispersal.

1. It is advantageous to animal transport of seeds if fruits of heavy-seeded *Yuccas* do not split open. Indehiscence of pods enables animals to locate, grasp, and transport the fruit and seeds together. Dehiscence would cause a scattering of seeds prematurely, making them more difficult for animals to locate and damaging the fruit wall, which is itself an attractive animal food.
2. It is likely advantageous for animal-transport of seeds if the fruits abscise, dropping into the leaf crown or onto the ground near the parent plant. In either case, the deciduous trait makes fruit available in or near the plant. Collection of the seeds by animals would be less efficient if the pods were to remain attached, high up on the inflorescence. Gnawed fragments of fruit with seeds inside are found near *Yucca* plants (Figure 8), and many animal burrows surround the heavy-seeded species of *Yucca* (Figure 9).
3. Thick fruit wall structure in heavy-seeded yuccas is likely an inducement for foraging animals to harvest and transport the fruit and seeds. Some of the thick-walled pods, especially those of *Y. baccata*, have been roasted and eaten by humans.
4. Erect pod posture would be of no obvious advantage in the transport of heavy seeds by animals and accordingly, pods are not all positioned erectly but point in various directions.
5. The shorter length of inflorescence and the shorter scape found in most heavy-seeded yuccas causes fruit to be held closer to the leaf crown (Figure 10). This may make it more



Figure 6. Three flowering stalks of a *Y. brevifolia* plant (commonly called the Joshua tree.) This specimen showing ripe indehiscent fruit was photographed 25 April 2003 near Palmdale, CA. Like most of the indehiscent and heavy-seeded yuccas, its fruit point in various directions. *Y. brevifolia* also illustrates the fact that yuccas depending on animal seed transport usually have their inflorescence extending only a short distance beyond the leaf crown—14 cm on average for *Y. brevifolia*. On the stalk at the right, some dried remnants of the inflorescences from previous years can be seen.



Figure 7. The same three *Y. brevifolia* flowering stalks shown in Figure 6 are seen here 81 days later (14 July 2003). Numerous pods have fallen during this time period. This deciduous character of pods in heavy-seeded yuccas is likely of help in enabling animals to harvest the fruit and thereby distribute the seeds.

likely that most fruits fall into the crown, allowing easier collection.

Seed Weights and Correlated Traits in the Literature

There was no information on yucca seed weight in any of the literature sources I consulted, even though the dimensions, colors, surface features, marginal rims (also called “wings”), and other traits of yucca seeds have been widely discussed (for examples, see Hochstätter, 2000, 2002, 2004; Small, 1933; Trelease, 1902; and Webber, 1953). Sargent (1921) measured the seed length and width for each *Yucca* species he covered, listing the presence or absence of a wing, but did not mention seed weight classes or the five other features coordinated with seed weight.

Characteristics of fruits, inflorescences, leaves, and stems have likewise been described and employed in the construction of taxonomic keys for the *Yucca* species (Bailey, 1939; Fernald, 1950; Hochstätter, 2000, 2002, 2004; Jepson, 1960; McDonald, 1973; Munz and Keck, 1968; Preston, 1961; Small, 1933; and Webber, 1953—to list a few). In these keys, however, no mention was made of the tie by which contrasting attributes are rather regularly correlated to either light or heavy seeds. And, I found no published hypotheses concerning possible functions of the features examined in this paper and the seed weights.

Some Correlations Already Reported

1. The Dehiscence or Indehiscence of Fruit as Discussed in *Yucca* Taxonomic “Keys”

Webber (1953) and Preston (1961) each utilized the dehiscence or indehiscence of pods as the factor in their keys intended for separating *Yucca* into two groups above the taxonomic level of “section.” Other workers also have made that same

Table 4. Average Seed Weights and Correlations Evident for Purchased Seeds of Certain *Yucca* Species Reported in Table 1.

Species of <i>Yucca</i>	Avg. Weight per Seed (mg) $\pm$ standard deviation	d = Pods Dehiscent i = Pods Indehiscent	+ = Correlation evident (dehiscent pod with low seed weight: or indehiscent pod with high seed weight.) - = Above Correlation not evident.
Light-Seeded			
<i>elata</i>	22 $\pm$ 4.25 n=87	d	+
<i>filamentosa</i>	10 $\pm$ 2.52 n=16	d	+
<i>glauca</i>	21 $\pm$ 7.02 n=53	d	+
<i>whipplei</i>	16 $\pm$ 4.64 n=14	d	+
Heavy-Seeded			
<i>aloifolia</i>	51 $\pm$ 9.55 n=9	i	+
<i>arizonica</i>	117 $\pm$ 34 n=19	i	+
<i>baccata</i>	135 $\pm$ 27.8 n=9	i	+
<i>brevifolia</i>	52 $\pm$ 11.7 n=14	i	+

separation based on dehiscence (e.g., Cronquist et al., 1977; McKelvey, 1938; and Gentry, 1972).

Sargent (1921, p. 111) did not use dehiscence versus indehiscence or deciduous versus persistent as salient fruit criteria for keying yuccas to the proper species. Recognizing a link between dehiscence and erect fruit, however, he did mention that *Y. elata*, being “capsular,” has erect fruit. But he did not state the reverse correlation of indehiscence with non-erect fruit. Patraw (1936, p. 38) reported that the pods of *Y. schottii* do not split open and that they fall off before winter, thus denoting a correlation in

that one species between the indehiscent and deciduous pod traits.

2. Dehiscent Pods, Dry Capsules, Erect Pods, or Other Features Correlated

Webber (1953, pp. 16–17) noted that those species that have dehiscent pods also produce a “dry capsule, soon becoming erect.” Small (1933) penned similar comments about *Y. filamentosa*. Thus dehiscence, dry fruit walls, and erect pods had been observed to coexist in yuccas many years before my 1986 paper was published. But concerning the converse choices involving indehiscence, Webber simply wrote the

word “indehiscent,” adding nothing about the features often associated with indehiscence (Webber, 1953, p. 16). McDougall (1973) correctly contrasted *Y. angustissima* with *Y. baccata* by stating that *angustissima* fruits are dry walled and dehiscent while those of *baccata* are “fleshy and indehiscent” (p. 103).

Benson and Darrow (1981) mentioned persistence of the capsule as being linked to the dehiscent fruit trait: “fruit drying and splitting open at maturity, the opened capsules persist on the old inflorescence through the winter” (p. 48). These authors did not indicate, however, that this pod persistence might play a functional role in wind transport of seeds.

In their corresponding key choice for indehiscent pods, Benson and Darrow (1981) correctly noted that where pods were indehiscent, the fruit was “fleshy or spongy, not splitting open, not persisting on the inflorescence through the winter” (p. 48). They did not state, however, that deciduous fruit might be part of a functional program to assist animals in the harvest and dispersal of seeds.

Irish and Irish (2000) described the relationship between the inflorescence and the leaf crown in 19 species of *Yucca*. They scored most of the dehiscent species as having the inflorescence extending above (or at least slightly above) the leaf crown. They classified most of the inflorescences of the indehiscent (heavy-seeded) species, on the other hand, as being half or more in the leaf crown, while listing some notable exceptions.

3. A Relationship of Dehiscent or Indehiscent Pods with Seed Shape

Webber (1953, p. 67) recognized the tie between the dehiscence or indehiscence of pods and the corresponding differences in the morphology of seeds (wings versus no wings, etc.) but did not report the correlation of dehiscence with the other traits enumerated here.

McDougall (1973) referred to the seeds of *Y. whipplei* as “very thin.”

Table 5. Predictions and Weights of Seeds Purchased for *Yucca* Species Not Included in the Field Study.

Species of <i>Yucca</i>	d = Pod Dehiscent i = Pod Indehiscent ^a .	Predicted Seed Weight: l = low if pod dehiscent, h = high if pod indehiscent ^b .	Seed Weight (mg) ± standard deviation	v = prediction verified (No predictions were falsified.)
Dehiscent				
<i>harrimaniae</i>	d	l	13 ± 2.87 n=24	v
<i>harrimaniae</i> subspecies <i>neomexicana</i>	d	l	10 ± 3.85 n=24	v
<i>pallida</i>	d	l	4 ± 3.24 n=25	v
<i>peninsularis</i>	d	l	22 ± 6.24 n=23	v
<i>rigida</i>	d	l	9 ± 3.64 n=10	v
<i>rostrata</i>	d	l	10 ± 3.3 n=41	v
<i>rupicola</i>	d	l	7 ± 1.73 n=25	v
<i>thomposiana</i>	d	l	6 ± 3.17 n=25	v
Indehiscent				
<i>australis</i> ^c	i	h	125 ± 18.9 n=22	v
<i>entlichiana</i>	i	h	39 ± 12.7 n=127	v ^d .
<i>faxoniana</i>	i	h	53 ± 8.53 n=16	v
<i>filifera</i>	i	h	57 ± 11.7 n=14	v
<i>mixtecana</i>	i	h	98 ± 16.9 n=10	v
<i>perisculosa</i>	i	h	103 ± 23.3 n=10	v
<i>valida</i>	i	h	57 ± 14.6 n=24	v

^a. It was determined from the literature whether the pod is dehiscent or indehiscent.

^b. The “prediction” as to *light* or *heavy* seed weight was made before purchasing and weighing the seeds. No information about seed weight was available in the literature.

^c. Hochstätter (2004, p. 33) had *Y. australis* as synonymous with *Y. filifera*. Based on the sizeable difference between the average seed weight for these two taxa here, however, I question that conclusion.

^d. *Y. entlichiana* seeds are rather light for an indehiscent species (39 mg), but they are still 17 mg heavier than *Y. peninsularis*, which is the heaviest of those with dehiscent pods.

Table 6. Field Data for the Five Dehiscent-Fruited Yucca Species Studied.

Species of <i>Yucca</i>	Altitude in Feet, if known	General Location	Associated Vegetation	Dates Observed Flowering	Dates Pods Ripe	Dates Old Pods Still Seen Present
<i>angustissima</i>	4500	At 6801 N. Hwy. 89, Chino Valley, AZ, Yavapai Co.	<i>Cylindropuntia</i> spp., <i>Platypuntia</i> spp., Also grasses including ring muhley, buffalo grass, and others.	17 May 2002 26 May 2003	15 July 2003	3 Feb. 2003 18 Apr. 2005
	5300	Along I-40 about 14 mi. W of Seligman, AZ, Yavapai Co. ^a	Grasses: various species including ring muhley. Also apache plume, pinyon pine, juniper.		15 July 2003 pods not open yet but almost.	1 Oct. 2007
	5300	Along I-40 about four mi. W of Seligman, AZ, Yavapai Co. ^b	Utah juniper, grasses (including ring muhley), prickley poppy, apache plume, and <i>Platypuntia</i> .			26 Aug. 2004 1 Oct. 2007
<i>elata</i>	2900	On east side of AZ Hwy. 71, 1.7 mi. S of interchange with Hwy. 93, 24 mi. NW of Wickenburg, AZ., Yavapai Co.	<i>Cylindropuntia</i> , mesquite, creosote bush, ironwood, and other desert shrubs.	26 May 2003	15 July 2003 4 Aug. 2003	4 Feb. 2003 25 Mar. 2002 19 Apr. 2005 26 Aug. 2004 1 Oct. 2007
	4850	Along AZ Hwy. 82 east-bound, 0.75 mi. E of interchange with Hwy. 83, Sonoita, AZ., Santa Cruz Co.	Grassland with sotol, catclaw acacia, agave, mesquite, and sunflower.	17 June 2002	15 July 2003	25 Mar. 2002 26 Aug. 2004 2 Oct. 2007
	4500	In a yard at Sierra Vista, AZ., Cochise Co.	In gravel surface along with saguaro and other cultivated desert plants.	15 May–7 June 2002		4 Aug. 2003 9 Aug. 2002
<i>filamentosa</i>		A business, Harrison Pike, Cincinnati, OH, Hamilton Co.	Planted at entrance of a business establishment.	25 June 2003		
		At a business, Brice Rd., Columbus, OH, Franklin Co.	Planted specimen in business parking lot.	10 June 2003		
		Near Newkirk, OK, Kay Co.	In yard of a farm.	11 June 2004		26 Sept. 2004
		South Shore Dr., Surf City, NC, New Hanover Co.	In vacant lot, one block west of the ocean.			15 Feb. 2003

Table 6 (continued)

<i>glauca</i>		Frontage lane N of westbound I-20, mi 170, W of Big Spring, TX, Howard Co. ^c	Farms and grassland.			18 Sept. 2002
		I-40, westbound, mi 126, roadside, NM, Valencia Co.	High desert.	13 June 2004	13 June 2004	
<i>whipplei</i>	2900	Escondido Canyon Rd. from CA Hwy. 14, Acton, CA, Los Angeles Co. ^d	Mixture of chaparral and Mohave Desert plants: California juniper, bladderpod, false buckwheat, <i>Platyopuntia</i> , Mormon tea,	18 Apr. 2005 18 May 2002		
	1380	Chaparral woodland across from 23544 Maple St., Santa Clarita, CA, Los Angeles Co.	Chaparral: greasewood, purple sage, white sage, California sagebrush, California coast live oak, horehound.		29 July 2004	15 Aug. 2004 1 Nov. 2007

a. Right shoulder of eastbound I-40, miles 105.8–107.

b. Right shoulder of eastbound I-40, miles 114.5–116.

c. Other locations where *Y. glauca* was studied include I-10, mile 73 off-ramp, near Fort Hancock, TX., Hudspeth Co.; N of Woodland Park, CO, Teller Co.; and along US Hwy 24 near Manitou Springs, CO, El Paso Co.

d. Go 0.2 miles SE on Escondido Canyon Road, then hike N of road into mixed desert-chaparral woodland.^e

McKelvey (1947) also recognized that seeds in the dehiscent [capsular] species of *Yucca* are relatively thin: “seed in the capsular species is thinner than in the baccate” (p. 12). But McKelvey did not speculate on possible seed-dispersal roles that this relationship between dehiscent pods and thin seeds might play.

Modes of Pod Dehiscence and the Differentiation between *Yucca* Sections

Sargent (1921, p. 111) noted that the dehiscence of *Y. elata* fruit involves its splitting open on a line between the carpels (also called “locules”), in a manner known as “septicidal dehiscence.” In a capsule having “loculicidal” dehiscence, however, the splitting occurs *within* each carpel, so that the locule is itself cleaved open in the middle (Figures 2 and 3). Using this contrast, Webber (1953) placed *Y. whipplei* into its own taxonomic section (*Hesperoyucca*) because its pods ordinarily undergo loculicidal dehiscence. Pods of all the other dehiscent-fruited species (section *Chaenocarpa*) generally split in a septicidal manner—“capsule commonly septicidally...dehiscent” (Webber, 1953, p. 16)—and were accordingly all placed into a different section: *Chaenocarpa*. But Webber (1953) also qualified this statement about members of the *Chaenocarpa* by noting that some of them dehisce both ways, being “occasionally septicidally and loculicidally dehiscent” (p. 16).

In the key of his first yucca book, Hochstätter (2000, p. 13) used this dehiscence distinction to separate *whipplei* from the other dehiscent-fruited yuccas. By the time he wrote his third volume in 2004, however, he no longer proposed it as a criterion. In that third book (Hochstätter, 2004), he separated *Hesperoyucca* from *Chaenocarpa* by means of inflorescence length and other inflorescence traits, without any reference in the key to the mode of pod dehiscence.



Figure 8. Pods and seeds on ground under a *Y. shidigera* plant, Kelbaker Road, Mohave National Preserve, CA, 15 July 2003. The *Y. shidigera* pod (lower center) is deciduous, does not split open (indehiscent), and has heavy seeds. These and other characteristics putatively prepare the plant for animal seed transport. Marks caused by the gnawing of animals can be seen on this fruit.

The Very Short Scape of *Y. shidigera*

McKelvey (1938) reported that the scape of *Y. shidigera* can be as long as the rest of the inflorescence: “scape 15 cm. in length or at times as long as inflorescence proper” (p. 92). Table 1 shows that the *Y. shidigera* inflorescence protrudes above the leaves only 17 cm on average. Figure 10 shows a *Y. shidigera* with its entire inflorescence

surrounded by leaves of the crown. Furthermore, the length of the scape on the *shidigera* plants that I measured (near Barstow, CA and at the Mohave National Preserve) was usually zero—no scape at all (Table 2). This suggests that *Y. shidigera* fits the pattern for a heavy-seeded species quite well. My observations conflict, however, with those of McKelvey (1938) and this warrants additional analysis.

A Taxonomic Suggestion

Pod dehiscence or indehiscence is presently considered to be a salient taxonomic trait that has long been used to divide the genus into two great but unnamed groups (Hochstätter, 2000). It would be reasonable and useful therefore to establish names for these two taxa. Perhaps they should have the category designation of subgenera, beneath the level of genus but above the level of section.

One proposed subgenus has dehiscent fruit and thus includes all the species in the sections *Hesperoyucca* and *Chaenocarpa*, which putatively bear light seeds. If it is found that the rest of the species in *Chaenocarpa* not weighed here do in fact have light seeds, this subgenus could be called *Oligosperma* (Greek: light seeds). The other subgenus would then contain the heavy-seeded (indehiscent) yuccas and might be called *Barysperma* (Greek: heavy seeds)—if the rest of its species are found to have relatively heavy seeds. The subgenus *Barysperma* would contain the sections *Yucca* and *Clistocarpa*.

Obvious Exceptions to the Correlated Features

1. Not All Heavy-Seeded Species Have Short Inflorescences

Recognized exceptions to the correlated traits can be seen in the tables. *Y. torreyi*, *Y. aloifolia*, and *Y. arizonica* are heavy-seeded species, but they have unusually long inflorescences. I found nothing in the literature about the seed weight of *Y. gloriosa*, but it probably has heavy seeds too. Along with *Y. torreyi* and *Y. aloifolia*, *Y. gloriosa* has a long inflorescence, while most yucca species (having heavy seeds) produce short inflorescences in which the fruit is borne either in the leaf crown or not very high above it (see Figure 10). The associations in the heavy-seeded species are “often” (but not always) present and trait 5’ (short inflorescence) is not characteristic of a few of the heavy-seeded species.

2. The Short Inflorescence of *Y. glauca*, a Light-Seeded Species

Fernald (1950) wrote concerning *Y. glauca* that leaf tips are almost as high as the peduncle (flower stalk), with “peduncle little overtopping the leaves” (p. 438). This means that the flower stalk is almost entirely surrounded by the leaf crown. The data in Table 2 of this paper shows that *Y. glauca* inflorescences protrude



Figure 9. A possible animal burrow near a *Y. brevifolia* plant, Pearblossom, CA. Fallen pods can be transported readily by animals such as pack rats.

only 40 cm above the leaf tips, whereas the average distance of such protrusion for the inflorescence of dehiscent species was 111 cm. But even though *Y. glauca* inflorescences are relatively short, they are taller than what Fernald described, an apparent discrepancy that deserves further investigation.

3. The Unusually Dry Fruit Walls of Two Indehiscent Species

Since *Y. brevifolia* has heavy seeds, it ought to likewise have a thick, fleshy fruit wall, not a dry one. The wall of *Y. brevifolia*, however, is dry and thus resembles the fruit wall of the dehiscent yucca species (McKelvey, 1938, p. 92). Nonetheless, the *Y. brevifolia* fruit wall is thick and spongy on maturity, not thin, so it is unlike the thin fruit wall of the dehiscent yuccas. Based on this dryness

of its ovary wall and on other traits, *Y. brevifolia* has been separated into its own taxonomic section (*Clistocarpa*), while all the other indehiscent yuccas are put into a different section, now called “*Yucca*.”

Y. gloriosa also has indehiscent fruit and accordingly should have a fleshy fruit as well. But Preston (1948, p. 369) wrote that the fruit of *gloriosa* has “thin dry flesh.” Bailey (1939, p. 353) also classified the fruit wall of *gloriosa* as being “dry.” But all the other indehiscent yucca species (except *brevifolia*) have fleshy fruit. Thus, both *Y. gloriosa* and *Y. brevifolia* have fruit walls that are exceptionally dry for indehiscent *Yucca* species.

(continues, p. 172)

Table 7. Field Data for the Eight Indehiscent Yucca Species Studied.

Species of <i>Yucca</i>	Altitude (Feet) if known	General Location	Associated Vegetation	Dates Observed Flowering	Dates Pods Ripe	Dates Pods Falling	Dates Pods All Gone
<i>aloifolia</i>	unknown	In a yard on MS Hwy 588, several mi. W of Ellisville, MS, Jones Co	These were possibly native or else planted, among pine trees	2 May 2002	13 Feb. 2002 (pods from 2001 season)		
	unknown	Lawn along NC Hwy. 17 near Jacksonville, NC, Onslow Co.	Probably planted	14 June 2002			
	unknown	Near 38 th and Ocean Blvds., Myrtle Beach, SC, Horry Co	In yards and pine woodlots close to Atlantic Ocean with <i>Y. gloriosa</i>		15 Feb. 2002 (from 2001 season)		
	unknown	In a front yard facing beach, S. Shore Dr., Surf City, NC, Janover Co	Close to Atlantic Ocean with <i>Y. gloriosa</i> and <i>filamentosa</i>		15 Feb. 2002 (from 2001 season)		
<i>arizonica</i>	3950	E side of AZ Hwy 82, 150 yds S of N Royal Rd & 0.1 mi S of "3 mi" sign, Nogales, AZ, Santa Cruz Co	prickly poppy, coachwhip, catclaw acacia, sotol, oak-mesquite-grassland	19 April 2005 21 April 2002 27 April 2002	3 August 2003	20 Oct 2007	
	3900	E side of AZ Hwy 82, 0.4 mi N of "9 mi" sign, E of guard rail. From 10.8 to 11.2 mi on E shoulder, Nogales AZ, Santa Cruz Co	<i>Y. schottii</i> , mesquite, grasses, <i>Agave sp.</i> , oak, prickly poppy, sotol	late April 2002	3 August 2003 late pod stage		
<i>baccata</i>	4200	99 mi E of Barstow (44 mi west of Needles, CA). Go N and W on Essex Rd from I-40 to Black Canyon Rd, then N 10 mi to Hole-in-the-Wall Campground, Mohave National Preserve, San Bernardino Co	holly grape, cholla, cat claw acacia, snakeweed, <i>Y. shidigera</i> , ironwood, mormon tea, pencil cactus	9 April 2003 25 April 2003 1 May 2002	25 May 2003	1 Oct 2007	

Table 7 (continued)

<i>baccata</i> (continued)	4040	6 mi E of Kingman AZ, DW Ranch Rd 0.2 mi S of I-40 parking area W side of rd. Grove is 360' S on dirt rd., Mohave Co	desert grasses, shrubs, <i>Cylindropuntia spp.</i> , palo verde, cat claw acacia, snakeweed, holly grape	9 April 2003 18 April 2005 25 April 2003	26 May 2003	14 July 2003	4 Aug 2003 26 Aug 2004 1 Oct 2007 1 Dec 2001 12 Jan 2002
	unknown	S of Congress AZ on AZ Hwy 89, 2 mi N of "271 mi" sign	creosote bush, ironwood, <i>Platyopuntia spp.</i> , <i>Cylindropuntia spp.</i>	19 April 2005	19 April 2005		
<i>brevifolia</i>	2940	Intersection of Pearblossom Hwy and Sierra Hwy, grove 150' NEE of traffic light and extending E for 300', Palmdale, CA, Los Angeles Co	Mohave desert flora: California juniper, <i>Platyopuntia spp.</i> , <i>Y. whippleii</i> , fiddle-neck, gold fields, filaree, California goldenbush and California poppy	9 April 2003 18 April 2005	9 April 2003 18 April 2005 25 April 2003 25 May 2003	25 May 2003 14 July 2003 24 Aug 2004	14 July 2003 30 Sept 2007
	3040	along N side CA Hwy 138 (Pearblossom Hwy), 180' W of 123 rd St E, Pearblossom, CA, Los Angeles Co	a single <i>Y. brevifolia</i> several feet N of roadway with others nearby, creosote bush	9 April 2003	9 April 2003 25 April 2003 25 May 2003	25 May 2003	14 July 2003 5 Aug 2003 30 Sept 2007
	3380	Both sides CA Hwy 138, E of intersection of Hwy 138 with CA Hwy 18, both Los Angeles Co and San Bernardino Co, CA ^a	creosote bush, four-winged salt bush, gold fields, filaree, CA juniper, CA goldenbush, fiddleneck	7 March 2005 (early onset of flowering)			30 Sept 2007 (a few pods) 1 Dec 2001 (just a few pods left) 28 Jan 2003 1 Feb 2003 (a few pods left)
<i>gloriosa</i>	1195	24773 Valley St., Newhall, CA, Los Angeles Co	Two planted specimens on a lot now used for business. Other planted specimens in Los Angeles bloom either in May or September.	1 May 2004, 14 May 2007, and Sept 2007 (first two weeks)	No fruit has ever been seen to "set" here, even with artificial pollination		

(continues on next page)

Table 7 (continued)

Species of <i>Yucca</i>	Altitude (Feet) if known	General Location	Associated Vegetation	Dates Observed Flowering	Dates Pods Ripe	Dates Pods Falling	Dates Pods All Gone
<i>gloriosa</i> (continued)	sea level	Myrtle Beach, SC, Horry Co; Clermont Shores MS, Hancock Co; Surf City NC, New Janover Co	In NC and SC growing in beach sand of yards adjacent to houses. In MS near sea level, small woodlot of pines and oaks, 0.5 mi from Gulf of Mexico	These locations were visited in Feb, 2003; no plants seen flowering	No lingering fruit observed on <i>gloriosa</i> at any of these locations, Feb, 2003		
<i>schottii</i>	3900	E side AZ Hwy 82, 0.4 mi N of "9 mi" sign, E of a guard rail; 10.8-11.2 mi many on E shoulder AZ Hwy 82, Santa Cruz Co	with <i>Y. arizonica</i> , mesquite, century plant, oak, prickly poppy, cat claw acacia	18 July 2002 4 Aug 2003	4 Aug 2003		2 Oct 2007
	4050	Patagonia AZ, Santa Cruz Co	in Patagonia city park with elderberry, ash, and several large mesquite	4 Aug 2003	4 Aug 2003		2 Oct 2007
	5280	Coronado National Memorial. AZ Hwy 92 to CNM entrance rd. CNM entrance rd about 5 mi ^b	sycamore, oak, sotol, century plant, mesquite, pine	15 July 2003 18 July 2002 25 July 2003 29 July 2003 19 Aug 2003	18 July 2002 9 Aug 2002 12 Aug 2002 19 Aug 2003 23 Aug 2002	9 Aug 2002 23 Aug 2002	14 Sept 2002 11 Oct 2002 (just a few pods left) 20 Oct 2007
<i>shidigera</i>	2950	15 miles N of Victorville, CA, San Bernardino Co, I-15. Take Wild Wash Rd east to an unmarked rd. on which go S. At end of pavement, hike or drive 1 mi S and then hike W onto ridge separating unmarked rd from I-15, 900' E of I-15	Clocks, creosote bush, fiddleneck	9 April 2003 18 April 2005	18 April 2005 25 May 2003	14 July 2003 (many pods on ground, gnawed) 8 Aug 2003 (some still attached, most fallen)	30 Sept 2007

Table 7 (continued)

<i>shidigera</i> (continued)	3100	I-40 about 65 mi W of Needles, CA, San Bernardino Co. Go 0.7 mi NE on Kelbaker Rd. Hike 380' N into Mohave National Preserve	Grove of over 100 <i>Y. shidigera</i> with <i>Eriogonum inflatum</i> , creosote bush, Mormon tea, and other desert shrubs	9 April 2003 18 April 2005	18 April 2005		
<i>torreyi</i>	4700	Eastbound I-10, east of El Paso, TX, Hudspeth Co					
	4220	Van Horn, TX, near Pilot Travel Center, Culbertson Co					
	unknown	Rest stop along I-10 westbound, at about mi 138, west of Van Horn, TX, Culbertson Co					19 Sept 2002
	4440	I-10 west of Kent TX, mi 175, Culbertson Co					
	unknown	I-20 mi 3, TX, Reeves Co		11 Feb 2002			

- a. One very large *Y. brevifolia* near NW corner at intersection of Verbena St and Hwy 138, Victorville, CA, San Bernardino Co, was also studied. It is 18 mi E of the 138 intersection with Hwy 18. 3150' altitude.
- b. Other *Y. schottii* study locations: 6000' summit on AZ Hwy 90, N of Bisbee AZ, Cochise Co; 5200' on AZ Hwy 186 in Chiricahua National Forest, where *Y. schottii* grows with pine trees and alligator juniper; various locations along a road going into the Chiricahua Mountains from Portal AZ, west of the ranger station—growing at 5660' with ponderosa pine, oak, sycamore, mountain mahogany, and alligator juniper, as well as up to 7400' at Onion Saddle where *schottii* grows with white fir, Douglas fir, and ponderosa pine. All pods were gone at these locations 25 March 2002.



Figure 10. *Y. shidigera* (commonly called the Mohave yucca) growing near the Wild Wash Road exit of I-15 near Barstow, CA, 25 May 2003. Like many other species of heavy-seeded yuccas, the inflorescence of *Y. shidigera* can be completely surrounded by the crown of large leaves as seen here. This attribute may be part of a “package” aimed at assisting animals in the harvest and distribution of seeds.

4. The Peculiar Splitting of an Indehiscent Fruit in *Y. aloifolia*

Elias (1980, p. 908) remarked that the fleshy purple fruit of *Y. aloifolia* possesses these two attributes: (1) the ripe pod does not drop off the inflorescence and, yet it (2) sheds its seeds while the pod is still attached to the plant. Elias (1980) supplied no further details regarding these events, which are different from the usual dehiscence of pods of the heavy-seeded yuccas. I examined the *Y. aloifolia*s in Mississippi twice and found that their fruit was indeed indehiscent. I was unable to examine these plants

later, however, to determine whether or not the pods split open, distributing the seeds while the pods are still attached to the inflorescence.

Current Reproduction by Seeds in Western Yuccas

Yucca plants carry out vegetative reproduction horizontally, but they also produce generous quantities of seeds. Reproduction by seeds in the southwestern United States, however, is probably not as prevalent now as it was hundreds of years ago. It is generally believed that in the past there was greater humidity

in western yucca habitats. Hochstätter (2000) indicated that yucca reproduction by seed in the wild is presently quite restrained, “suggesting that current climatic conditions are less than favorable” (p. 13).

Webber (1953) wrote about reproduction by seedlings, “although the southwestern yuccas produce an abundance of viable seed, reproduction by seed is very limited” (p. 71). Webber tabulated all the seedlings he could find for 21 yucca species over a period of four years and noted that the numbers were very small, even zero for some of

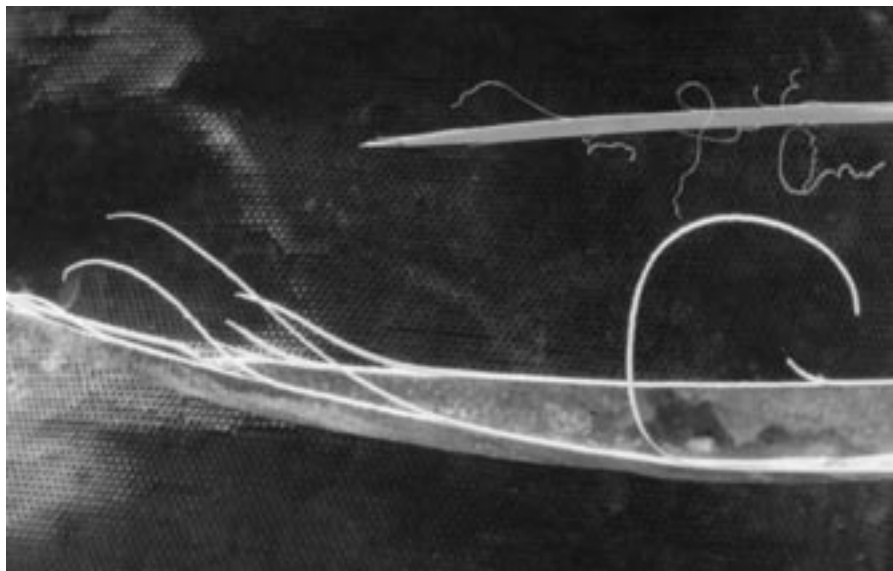


Figure 11. Leaves of *Y. shidigera* (below) and *Y. angustissima* (wisely called the narrow-leaved yucca) above. These fibers threading away from a leaf margin may be wide as in *Y. shidigera* (below) or narrow—*Y. angustissima* (right). Leaf margin characteristics appear in parallel fashion among various indehiscent and dehiscent (heavy-seeded or light-seeded) yuccas with little or no clue concerning phylogeny. Vegetative attributes such as these are not correlated to the two seed-distribution “packages” of traits. This lack of correlation for some traits coupled with correlation for seed-dispersal traits creates a problem for evolution theory.

the species. He attributed this decline in reproduction by seeds and seedlings to three factors: meager and irregular rainfall, slow growth, and rodent damage. Campbell and Keller (1932) found that reproduction by seeds in *Y. elata* is quite limited because “few seedlings become established, and their growth is extremely slow” (p. 371), which was caused, in their opinion, by the limited growth of seedling root systems. The growth rate they reported for *Y. elata* seedlings was one inch per year (Campbell and Keller, 1932, p. 373.)

The origins model that includes a global flood indicates that the drying of the western yucca habitats is one of the continual changes in climate that have been occurring for centuries following the Flood of Noah. The numerous scientific papers discussing

this possible post-Flood climatic shift include Williams et al. (1992). In any case, the seed-distributing mechanisms of the yuccas were likely of greater importance back when the southwestern U.S. was more mesic and favorable to seed germination and the establishment of yucca seedlings.

Wind Distribution of Yucca Seeds in the Literature

The only reference I found to yucca seeds being carried by wind was in Campbell and Keller (1932), concerning *Y. elata*: “The seeds are light and well disseminated by wind when the pods open during the late summer and autumn” (p. 371). Having written this, however, they did not mention any of the other factors that may work together with light seeds to make wind distribu-

tion feasible for members of what I am calling the subgenus *Oligosperma*.

Literature Citations on the Possible Distribution of Yucca Seeds by Animals

I found only three comments regarding animals interacting with yucca plants. Concerning *Y. shidigera*, Jaeger (1940) reported that “pack rats often gnaw off the bitter outer covering of the fruit, which is rich in sugar” (p. 19). Baerg (1973) asserted that *Y. brevifolia* is “food for various desert animals, chief of which is probably the pack rat” (p. 61). Regarding the soft, fleshy fruit of *Y. aloifolia*, Elias (1980) commented that it is bitter and is “not favored by wildlife” (p. 907). On several occasions, during daylight hours and from secluded locations near *Y. baccata* plants bearing ripe pods, I monitored the plants but did not observe any animals harvesting the pods. Figure 8 shows marks of chewing on fruit of *Y. shidigera*, possibly made by pack rats. The holes and burrows of animals are frequently found near individual *Y. brevifolia* plants (see Figure 9).

A Major Scientific Problem Facing the Origin of Yucca Species by Evolution

As shown in the “Results” section, traits involved with seed dispersal are well correlated with each other (Tables 1, 2, 4, and 5), whereas vegetative characteristics (Table 3) are neither correlated with the dispersal features nor correlated among themselves in the *Yucca* species. This intermingling of six well-correlated seed-dispersal features with more than six vegetative traits that are uncorrelated is antithetical to patterns expected to arise from neo-Darwinian evolution. If one phylogeny were proposed on the basis of the vegetational and ecological traits (Table 3, 6, and 7) while another were based on the seed dispersal features (Tables 1, 2, 4, and 5), two very different and highly speculative schemes of “relatedness” or “descent” would emerge.

This contrasting coexistence of features correlated to seed dispersal and other uncorrelated characteristics suggests that the distribution of traits in the *Yucca* species has had little to do with the natural selection of gene mutations and much to do with conscious control. I discussed this evolutionary puzzle previously:

The present three yucca groups (or the four groups of Benson and Darrow) do not submit easily to an evolutionary scheme of development. There is not . . . a coherent and phylogenetic distribution of traits in these three groups but instead, a series of embarrassing parallelisms between members of different groups (Howe, 1986, p. 13).

Correlation of traits related to seed dispersal and the simultaneous lack of correlation for other traits fits well with the idea that a plan for efficient seed distribution was executed during the origin of the yucca species.

Research Possibilities

A careful analysis of fruit and seed characteristics should be made for *Y. gloriosa*. Further study should be undertaken concerning a possible bi-seasonal (spring and fall) flowering for *Y. gloriosa*, as I observed in California (Table 7). Studies also should be made to determine what factors cause fruit production to be scarce in *Y. gloriosa* (Sargent, 1921).

Knowledge of the feeding habits of various animals on yucca fruits could be obtained by using surveillance cameras at night when the pods are ripe. A study might be made on what effect (if any) the presence of the so-called “wings” or “marginal rims” has on wind-transport

of yucca seeds. Yet another area of research would be to test the aerodynamic properties of both light and heavy yucca seeds.

Additional Predictions

Based on the existing associations of characteristics, more predictions are possible and can be evaluated in later yucca analyses. The hypotheses allow the following prediction for the yuccas not yet studied:

1. Those species bearing dehiscent pods will be found to have relatively light seeds.
2. Species with light seeds and dehiscent fruit will likewise manifest the four other accompanying features.
3. Species bearing indehiscent pods will possess heavy seeds.
4. They will usually possess the other four features correlated with indehiscent fruit and heavy seeds.

As the remainder of the 49 species and 24 subspecies of *Yucca* are studied, it will become clear how strongly these four predications will be supported.

Conclusion

There is a consistent correlation of certain morphological traits with seed weight in yuccas. It is proposed that these coordinated features foster seed transport by two distinct means—wind and animals. I am unaware of such a correlation being previously reported. This pair of dispersal systems illustrates a skillful origin carried out by the Creator, showing distinct features of design even at the inter-species taxonomic level.

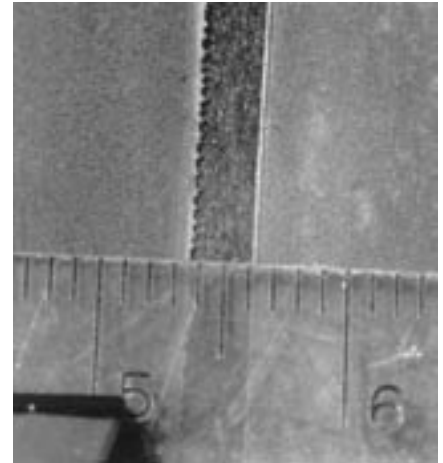


Figure 12. Close-up photograph of yucca leaf margins—serrated margin of *Yucca aloifolia* on the left and smooth leaf margin of *Y. gloriosa* on the right. A millimeter ruler is below both leaves. Smooth, serrated, and fibrous margins; wide or narrow leaves; curved or flat leaves; green versus blue-green overall leaf color, mountainous or desert habitat, and many other vegetative attributes are found distributed here and there, throughout the four yucca sections in rather parallel fashion. This provides very few phylogenetic evidences for building a “tree” of evolutionary descent among yucca species. On the other hand, the seed-dispersal traits are in consistent “packages” that suggest purposeful programming in origins.

Appendix I. Comparisons between nine southwestern species of yucca according to 11 contrasting traits (from Howe, 1986).

Species Characteristics	<i>angustissima</i>	<i>arizonica</i>	<i>baccata</i>	<i>brevifolia</i>	<i>elata</i>	<i>glauca</i>	<i>shidigera</i>	<i>schottii</i>	<i>whipplei</i>
1. Leaf margin	fibers	a few fibers	fibers	serrations	fibers	fibers	fibers	no fibers no serrations	serrations
2. Leaf width* in mm± S.D.	narrow 4.2 ± 1.80 n=10	narrow	Broad 22.3 ± 3.25 n=22	narrow 9.7 ± 1.17 n=20	narrow	narrow	broad 29.2 ± 3.74 n=10	broad	narrow
3. Leaf color	blue-green	———**	blue-green	blue-green	yellow-green	———	yellow-green	yellow-green	blue-green
4. Leaf cross section plano or concavo convex	plano	concavo	concavo	plano	plano	plano	concavo	concavo	plano
5. Trunk	absent	erect but obscurely so	procumbent	erect	erect	absent	erect	erect	absent (under-ground)
6. Inflorescence character	raceme	panicle	panicle	panicle	panicle	raceme	panicle	panicle	panicle
7. Inflorescence length	long	long	short	short	long	long	indeterminate	indeterminate	long
8. Fruit stance	erect	not erect	not erect	not erect	erect	erect	not erect	not erect	erect
9. Fruit splitting?	dehiscent	indehiscent	indehiscent	indehiscent	dehiscent	dehiscent	indehiscent	indehiscent	dehiscent
10. Fruit fall?	persistent***	deciduous****	deciduous	deciduous	persistent	persistent	deciduous	deciduous	persistent
11. Altitude and ecological associations	high with pinyon pine and juniper	low 2000–4000 feet	high with pinyon pine and juniper	low with creosote bushes	low with creosote bushes	high with pinyon pine and juniper	low with creosote bushes	high with oak woodland	low with chaparral

* A mean followed by the standard deviation (in millimeters) is given for each of two typically “narrow leaved” species and two “broad leaved” species. n is the number of leaf width measurements taken.

** A blank line indicates that field and/or library data were not available.

*** In the 1986 paper this said “deciduous”—an error. Needs to read “persistent.”

**** Left blank in the 1986 paper—now known to be “deciduous.”

Acknowledgments

The sagacious Creator merits foremost acclaim for having purposefully produced yucca plants and for having ensured their reproduction. I thank donors to the Creation Research Society Research Endowment Fund and members of the CRS Research Committee for making financial support available to cover some of the costs of the field and laboratory studies. I am grateful for the help afforded me in the field and with the botanical literature by Stephen B. Austin. Keith and Mary Wambach likewise deserve recognition for having given capable assistance in the study, photography, and phenology of *Yucca schottii* and *Y. elata*. Kenneth and Wilma Hynd provided aid in the work with *Y. filamentosa*. Peg Westphalen deserves credit for securing many literature items through interlibrary loan.

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Although I am personally responsible for all errors or omissions in this paper, I thank the following individuals for assistance in improving the manuscript: Jerry Bergman as my editor, together with a very helpful group of referees—Stephen B. Austin, Emmett Williams, and Margaret Helder. I thank Mark Armitage for preparing the photographs for publication.

I want to express gratitude to those who, over many decades, carried out classical studies on this great genus *Yucca*. I convey special appreciation to Fritz Hochstätter, whose three recent monumental volumes on yucca helped make my own analyses and predictions possible.

Glossary

abscission (n): the falling off of a piece or organ of a plant, such as a seed pod.
abscise (v): to fall off of a plant, e.g., a seed pod.
baccate (adj): fleshy, indehiscent, deciduous, like the pods of *Y. baccata*.
carpel (n): one of the sections of a compound fruit or ovary.
capsule (n): a dry yucca fruit like that of *Y. whippleii*.
capsular (adj): like a capsule—dry.
category (n): any of the levels in the hierarchy of classification—e.g., family, genus, etc.
Chaenocarpa (n): one of the taxonomic “sections” in the genus *Yucca*.
Clistocarpa (n): one of the taxonomic “sections” in the genus *Yucca*.
crown (n): the circle of leaves at the top of a yucca stem.
crown height (n): the distance from ground level up to the crown of a yucca plant.
deciduous (adj): a plant organ (e.g., leaf or pod) that is prone to falling off the plant.
dehisce (v): to split open, as some pods are able to dehisce.
dehiscence (n): a splitting open of an organ—e.g., a pod.
dehiscent (adj): prone to splitting open—e.g., a pod of *Y. filamentosa*.
evolution (n): the descent of all taxa from a common ancestry by mutation, natural selection, and other natural processes.
fibrous (adj): having slender fibers attached as in a fibrous leaf margin.
Hesperoyucca (n): one of the four taxonomic “sections” in the *Yucca* genus.
indehiscent (adj): not prone to splitting open as a pod of *Y. schottii*.
indehiscence (n): the quality of not splitting open.
inflorescence (n): a stalk bearing flowers and ultimately fruit.
key (n): a series of paired choices useful in identifying a living organism.

leaf crown (n): a circle of leaves atop a yucca stem.
locule (n): a carpel or cavity of a compound ovary.
loculicidal (adj): given to splitting open in a carpel in the middle.
loculicidally (adv): refers to the splitting open of a carpel in its center.
morphology (n): the form of an organ—here, of a plant organ such as a leaf or fruit.
non-deciduous (adj): not prone to falling off the plant—e.g., pods of *Y. elata*.
numerical taxonomy (n): a mathematical classification evaluating the many similarities and differences existing between the various groups involved.
peduncle (n): an inflorescence, or flower stalk.
persistence (n): the quality of remaining on the flower stalk, not falling off.
persistent (adj): not falling off the flower stalk, remaining attached.
phenological (adj): pertaining to events occurring on an annual, seasonal basis.
phylogenetic (adj): related to a supposed long-term descent from common ancestry.
pod (n): a fruit; ripened ovary.
scape (n): a lower section of an inflorescence bearing no flowers.
section (n): a category level in plant taxonomy below a subgenus and above a series.
septicidal (adj): at the edge of a carpel, along the line where two carpels of a compound ovary meet, as in septicidal dehiscence of a pod.
septicidally (adv): in such a way that it occurs at the juncture between two carpels.
serrated (adj): having a saw-toothed character, as in serrated leaf margin
standard deviation: (abbreviation = S.D.)

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n}}$$

standard error of the sample mean: (abbreviation = S.E.)

$$se = \frac{s}{\sqrt{n}}$$

subgenus (pl. *subgenera*) (n): a taxonomic category level above a section and below a genus.

subspecies (n): a taxonomic category level below that of a species.

suture (n): a line along which a dehiscent pod may split.

taxon (pl. *taxa*) (n): any particular group in the taxonomic system, such as *Chaenocarpa* (a particular section in the genus *yucca*) or *filamentosa* (a particular species in genus *Yucca*).

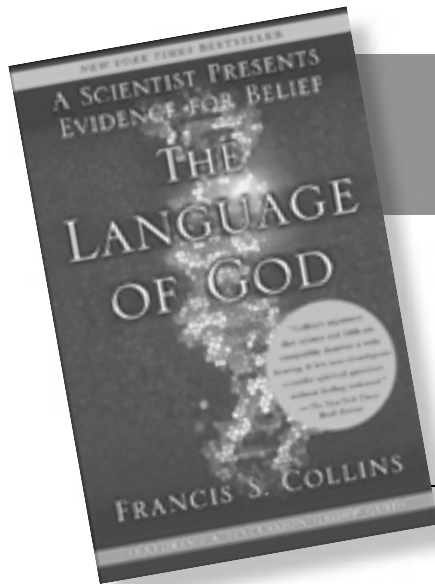
taxonomic (adj): having to do with the science of taxonomy.

taxonomy (n): the science of classifying and naming living organisms.

Yucca (n): one of the four sections in the genus *Yucca*.

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Book Review

A Scientist Presents Evidence for Belief, The Language of God

by Francis Collins

Free Press, New York, 2006,
305 pages, \$15.00.

The Language of God is written by Francis S. Collins, head of the U.S. government's portion of the Human Genome Project, which assembled the first draft of the human genome. Born in a family of free thinkers, Collins evolved from agnostic to atheist during university studies. Later, as a physician, he was influenced in the opposite direction by reading C. S. Lewis and realizing that there was a universal moral law: All people recognize a difference between right and wrong. Looking for evidence to strengthen his position as an atheist, he allowed his mind to explore possibilities. He found, as had C.S. Lewis, that the evidence for God was difficult to ignore.

The odds against a universe like ours, capable of producing a planet where life could exist, are enormous and suggest the possibility of divine influence. There also is the question of how a self-replicating information-containing molecule like DNA or RNA can form spontaneously. Collins concluded that despite substantial effort by multiple investigators, formation of the basic building blocks of RNA was not achieved in a Miller-Urey type of experiment, nor has a fully self-replicating RNA been possible to design. Yet these molecules, complete with the information they contain, are universal to all known forms of

life, a problem that brought the famous atheist Francis Crick to suggest that someone brought life to earth from some other place in the universe. Collins says this suggestion does nothing to resolve the problem of life's origin but instead puts it off to another location. Collins does not claim that these problems prove that God created life, but they show the difficulty atheists have in finding another satisfactory solution. Collins's position is that evolution, as a mechanism, can and must be true, with nothing said about its author.

Collins repeats some of the usual mistakes used as evidence for evolution by evolutionists who reject God. Thus, the eye evolved from a "simple pigment-ed pit" like that of the flatworm. Those who repeat such statements do not take into account the abundant advanced trilobite lenses found in the very early Cambrian strata.

Collins holds proponents of intelligent design to extremely high levels of proof regarding the formation of the bacterial flagellum, often used as an example of intelligent design. His supposedly winning argument that invalidates intelligent design is the speculation that the flagellum did not come about by design, but evolved from an earlier stage: "Presumably, the elements of this structure were duplicated hundreds of millions of years ago, and then recruited for

a new use" (p. 192). Collins believes that God, to some extent, directed evolution and did it well enough that He did not need to intervene periodically to directly design a flagellum or anything else.

Collins believes that man, the top of the evolutionary order, evolved from an ancestor that he had in common with the great apes. Man, however, was unique in that he had a spiritual nature, the knowledge of right and wrong, and a tendency to search for God, all characteristics that "defy evolutionary explanation" (p. 200). After scientific study brought Collins to believe in God, his desire to know God was blocked by his sinful desire to be in control. As he studied the crucifixion and resurrection of Jesus Christ, he realized that Jesus was the bridge between him and God. He explored the gospel, found it historically valid, then knelt one morning in the dewy grass and surrendered to Jesus Christ (p.225).

During the course of his life, Collins moved from agnostic to atheist, back to theist, and then to a believer in Jesus Christ as his savior. He now describes himself as a theistic evolutionist, and supporting that point of view is one aim of this book.

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Did Gene Duplication Produce Gene Families?

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Abstract

Gene duplication is a process that produces extra copies of genes within the genome. Gene families are groups of similar genes, which evolutionist biologists believe to be products of gene duplication. In this paper, I argue that gene duplication is not the source of all of the modern gene families for the following reasons. (1) Most of the documented gene duplications are detrimental, and when beneficial, they cannot lead to new molecular functions. (2) Duplicated genes are usually silenced epigenetically, followed by degenerative mutations, ending up in non-functionalization. (3) Members of gene families are often components of irreducibly complex systems. (4) Regulation hierarchies, which have no counterparts in lower organisms, are required for proper expression of gene families. I propose the following criteria to distinguish between DNA sequences that were duplicated in history and paralogous genes that were created individually: First, copy-number polymorphisms among individuals of the same species obviously demonstrate recent duplications. Second, components of irreducibly complex systems are not likely products of gene duplications. These include genes with complex regulation hierarchies. Additional criteria are that the degree of sequence homology is a poor indicator to determine whether genes are duplicated, and the duplication by transposition is possible but is normally suppressed.

Introduction

Gene duplication is a specific type of “mutation” that increases the size of the genome. Major mechanisms of gene duplication include polyploidy, polysomy, unequal crossing-over, and transposition. The fate of duplicated

genes, as well as the role of gene duplication in the history of life, has been a subject of much speculation and controversy. Most genes of “advanced” organisms have nonallelic homologues (paralogs) within the same genome,

forming gene families. The degree of homology and functional similarities between paralogous genes vary from family to family. Are all gene families produced by ancient duplication events? If not, how can one distinguish between historical duplication and common design at the time of creation? This paper explores gene duplication in the light of genome-stabilizing mechanisms, as well as empirical findings about the function and regulation of well-known gene fami-

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lies, and argues that gene duplication followed by mutation cannot produce new molecular functions and therefore could not have produced paralogs with different functions. Although unequal crossing-over may alter the number of genes within a cluster of paralogs, I will show it is not accountable for the origin of the cluster.

Phenotypes of Gene Duplication

Duplication of large chromosomal segments or entire chromosomes causes severe imbalance between genes, resulting in malformation or diseases. Down's syndrome (trisomy 21 in human) is the best-known example. Even small duplications within protein-coding regions may cause problems such as frame-shift mutations (O'Dushlaine et al., 2005).

In polyploidy, however, all the genes of the genome are proportionally duplicated. Because polyploidy reduces the probability of homozygosity of inferior alleles, polyploid species may display increased vigor compared with their diploid parents. Furthermore, allopolyploidy can produce fertile hybrids in plants. However, it is noteworthy that the "new" phenotypes in polyploid species are all quantitative, not qualitative (Otto and Whitton, 2000). In other words, gene dosage effects may increase the biomass of the organism but does not produce new genetic products, only old ones produced in altered quantities. Even in allopolyploidy, the hybrid species merely demonstrate a combination of parental traits encoded by preexisting parental genes (Figure 1), just like allodiploids.

Polyploidy is rare in animals and most always lethal in birds, mammals, and human. Possible reasons include:

1. Chromosomal sex determination. "Advanced" animals are dioecious (having male reproductive organs in one individual and female in another),

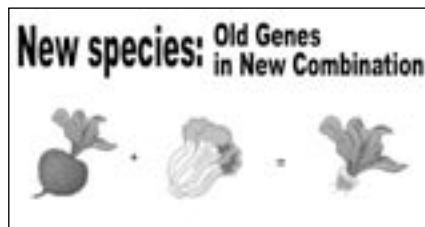


Figure 1. Allopolyploidy produces new species, but no new genes or new molecular functions. *Raphanobrassica*, a synthesis of radish (*Raphanus*) and cabbage (*Brassica*), has leaves of radish and roots of cabbage, therefore is inedible.

while most plants are not. Dioecy is typically determined by different combinations of sex chromosomes in male and female. In such animals, polyploidy leads to abnormal combinations of sex chromosomes, resulting in disturbed sexual development and sterility. However, this does not explain why most polyploid human and animals die as embryos.

2. Genetic imprinting. In a diploid species, some genes from one parent are preferentially expressed in the early embryo. This is achieved by epigenetic modification of DNA during gametogenesis. Polyploidy will interfere with the expression of imprinted genes and therefore disturb embryonic development. Consistent with this theory, digynic (formed from diploid eggs) and dispermic (formed from fertilization by two sperm cells) human triploids demonstrate different survival time and pathological characteristics (Zaragoza et al., 2000). Plants have a haploid gametophyte phase in their life cycle and use different control mechanisms of imprinting than those of animals (Scott and Spielman, 2006).

3. Response to increased cell volume and decreased surface-to-volume ratio may be different in plants and animals, since plants have simpler body organization than animals.

Silencing and Degradation of Duplicated Genes

The cell is endowed with mechanisms to suppress duplicate genes (homology-dependent gene silencing) to prevent overexpression of gene products, such as RNAi, DNA methylation, and heterochromatin formation. The best-known example is inactivation of the extra X chromosome in human females. In plants, introducing extra copies of a gene often causes silencing of both the transgene and the endogenous gene (Flavell, 1994; Napoli et al., 1990). Similar phenomena are also found in other organisms, such as in fungi, drosophila, and mammals (Bhat, et al, 2004; Garrick et al., 1998). Gene silencing is especially prominent in polyploids (Adams et al., 2003).

Silencing of duplicated genes by cytosine methylation has been extensively studied. While methylation is reversible, methylated cytosine bases are prone to undergo spontaneous deamination and become thymines. C-T transition in CG-rich sequences, known as CG suppression, is especially common among duplicated genes (Lund et al., 2003) (Figure 2). Post-transcriptional gene silencing by double-stranded RNA is also employed by the cell to suppress duplicates (Agrawal et al., 2003; Saumet and Lecellier, 2006).

Figure 3 summarizes current theories about the fate of duplicated genes. Due to the lack of purifying selection, the fate for the vast majority of duplicates appears to be nonfunctional (pseudogenization). It is also possible that they could be subfunctional, but that leads to differentiation without innovation. Epigenetic complementation (EC theory, see Figure 3d) is the only mechanism whereby the duplicates may escape degenerative mutations, but the theory is inconsistent with the fact that most gene families are clustered and therefore in the same epigenetic environment. No mechanism for a neofunctional state has been proposed in these theories (Liu and Moran, 2006).

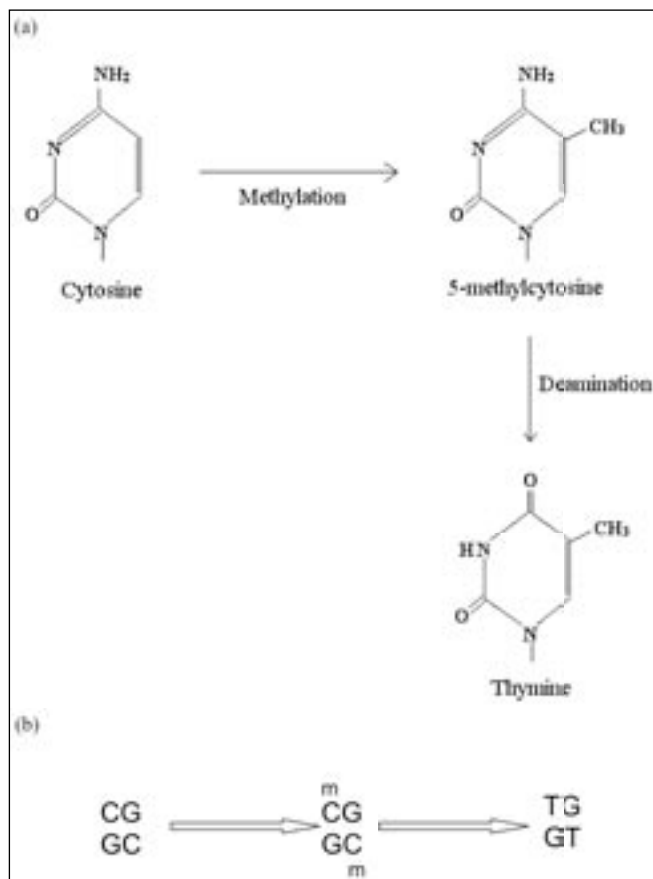


Figure 2. (a) Silencing by cytosine methylation. Spontaneous deamination of 5-methylcytosine may follow. (b) Transition of methylcytosine to thymine in CG islands inactivates a gene.

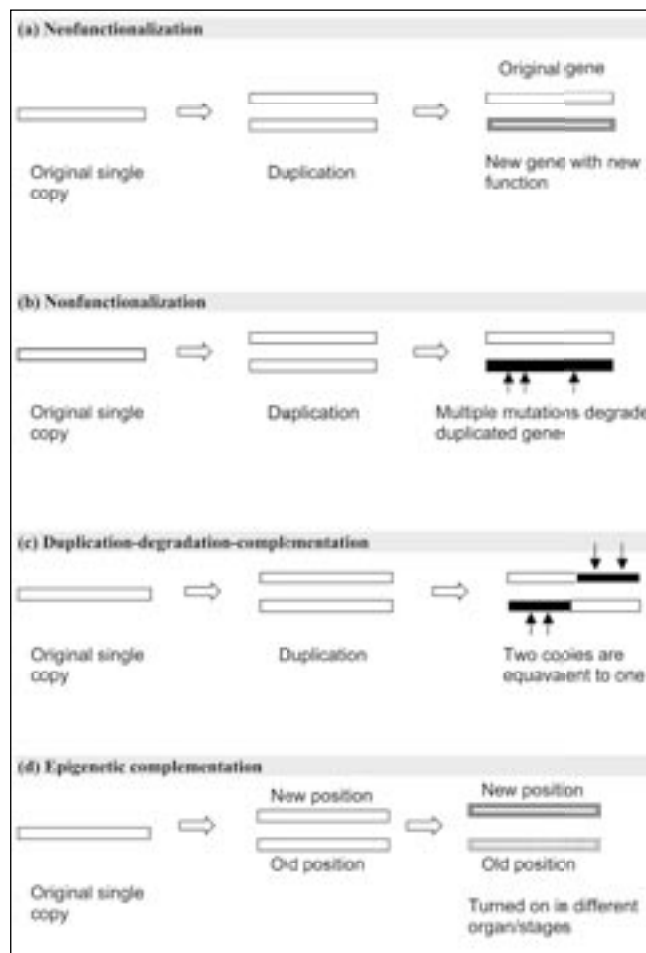


Figure 3. Proposed fates of duplicated genes. (a) Neofunctionalization of one copy while the other copy carries out the original function (Ohno, 1982; Taylor and Raes, 2004). (b) Nonfunctionalization of one copy due to accumulation of degenerative mutations (Lynch and Conery, 2000). (c) Partial degeneration of both copies may end up with two genes functioning as one (Force et al, 1999; Lynch and Force, 2000). (d) Duplicates function at different stages/organs depending on position (Rodin et al, 2005; Rodin and Riggs, 2003).

Duplication and Gene Families

Of the known gene families, some have members that are structurally and functionally quite different, while others may consist of identical copies of the same gene. Many biologists assume that the degree of homology reflects the time available for random mutations after duplication and also assume without direct evidence that the genes are in fact duplicates. Below are proposed some ru-

dimentary criteria to distinguish between historical duplications and gene families created in the beginning of life.

1. Irreducibly complex systems are not products of gene duplications. An irreducibly complex system is "a single system composed of several well-matched, interacting parts that contribute to the basic function, wherein the removal of any one of the parts causes the system to effectively cease functioning" (Behe,

1996, p. 39). Such a system cannot be built gradually by evolution. For example, several blood-clotting factors (factors II, VII, IX, and X) are homologous serine proteases. However, multiple duplication events must occur simultaneously, followed by coordinated creative mutations to produce a functional intermediate network from a proposed primitive clotting system (Davidson, et al, 2003; Liu and Moran, 2006). Some factors in

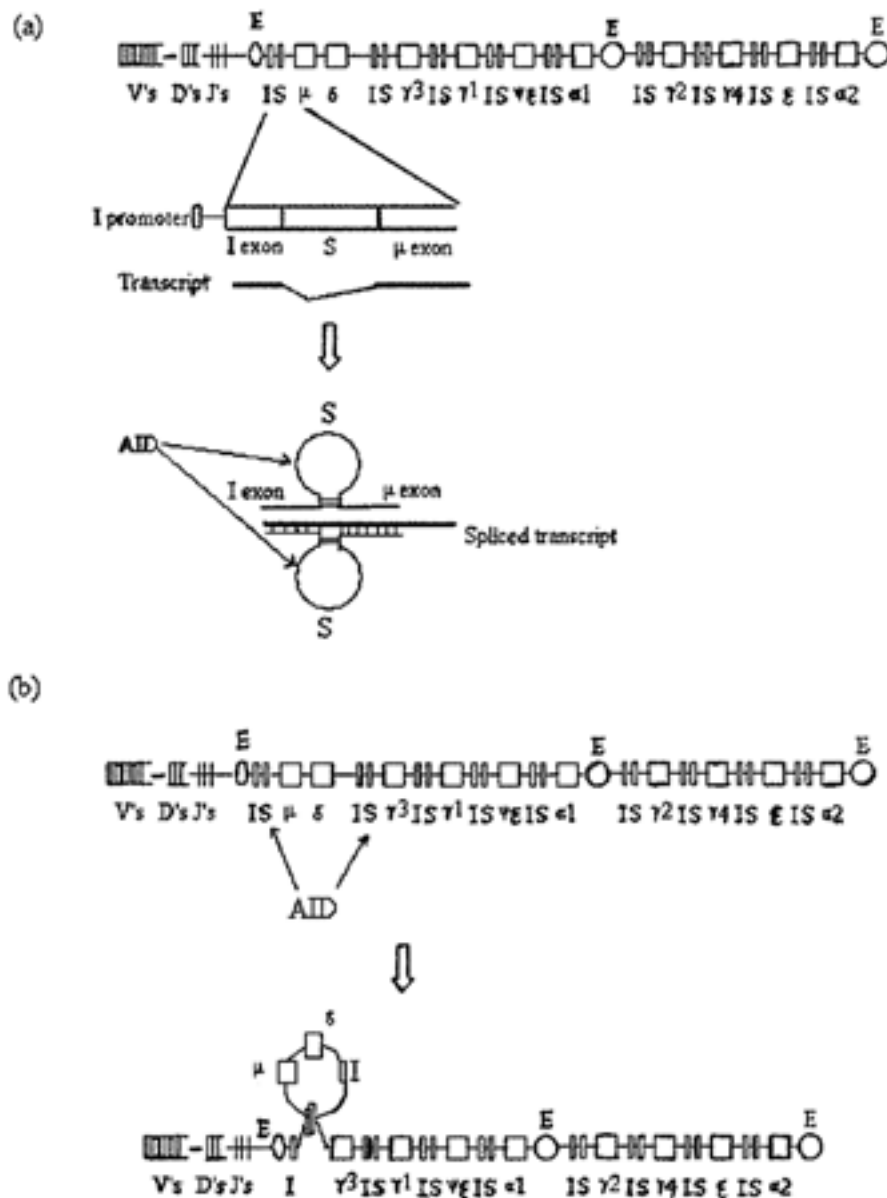


Figure 4. (a) Organization of the human immunoglobulin heavy chain constant locus. V, D, J: variable region genes; μ, δ, γ, ε, α: constant region genes; I: I promoter; S: switch region; E: enhancers. The region upstream of the μ heavy chain gene, including the I promoter, I exon, S region, as well as the 5' end of μ exon, is expanded to show an RNA transcript, which, after splicing, induces single-stranded loops in the S region. The loops, stabilized by both the transcript and stems formed from inverted repeats, are targets of the activation-induced deaminase (AID).

(b) AID recognizes the loops, deaminates cytosine, and in conjunction with uracil DNA glycosylase as well as an AP endonuclease, introduces double-stranded breaks in two S regions. The broken ends from different S regions are subsequently joined by the nonhomologous end-joining mechanism, eliminating the intervening sequences as a circle.

the system, such as factor V, do not have a preexisting paralog and therefore have to be created *de novo*.

2. Gene families with irreducibly complex regulation networks are not products of gene duplication. “Advanced” organisms have a significant fraction of their genomes as regulatory sequences, which have no homologues in simpler organisms (Liu and Doran, 2006). In systems, such as the immunoglobulin heavy chain genes, expression of the gene family is regulated with a unique set of cis and trans-acting factors that are not associated with the structural genes (Figure 4).

Expression of the constant region genes (μ, δ, γ, α, and ε) of immunoglobulin heavy chains is temporally regulated by a class-switch recombination mechanism illustrated in Figure 4. In humans and mammals, class switch requires simultaneous presence of two types of enhancers, the I promoters and S regions. Vertebrate animals lacking the S regions do not undergo class switching, even though they may possess linked heavy chain genes (Stavnezer and Amemiya, 2004). Deletion of any of these cis-elements in mice resulted in impaired class switching or no class switching (Cogne et al., 1994; Manis et al., 1998; Pinaud et al., 2001; Shinkura et al., 2003; Zhang et al., 1993).

The key enzyme, activation-induced deaminase (AID), is B-cell specific. Although it is also used in another process (somatic hypermutation of V regions), class switch requires a functional domain of the protein that is not needed for hypermutation (Barreto et al., 2003; Ta et al., 2003). There is strong evidence that other class-switch-specific enzymes/cofactors are required to guide μ—α, μ—γ, and μ—ε class switches (Ma et al., 2002; Ta et al., 2003).

Class switch also requires multiple enzymes involved in transcription, RNA splicing, excision repair, and nonhomologous end-joining (NHEJ) pathways. Although these enzymes are not class-

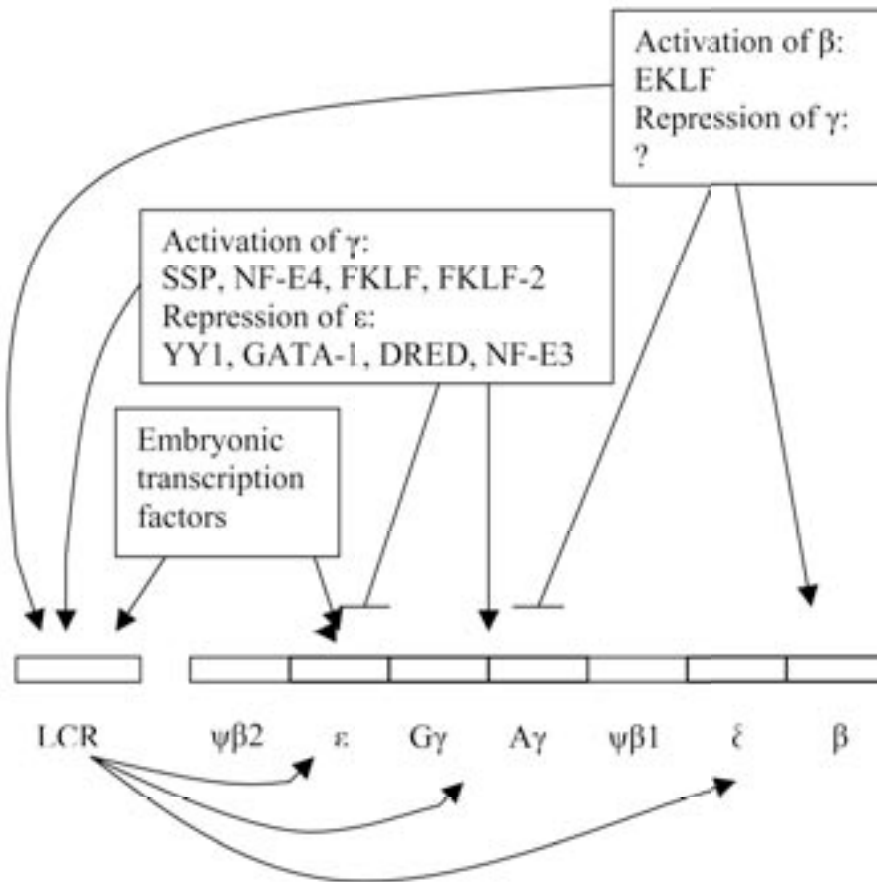


Figure 5. β -globin gene switching. Multiple erythroid-specific transcription factors act on the upstream locus control region (LCR) as well as the promoter of each gene to switch from embryonic (ϵ) to fetal (γ) then to adult (β and δ) globin types. -: repression; +: activation.

switch specific (and therefore could have evolved independently), their recruitment and coordination with the class-switch-specific factors necessitate careful design. For example, the spliced transcripts from I promoters are not translated, and their only known function is to initiate class switch. Production of these transcripts without simultaneous development of other factors for class switching would have been a mere waste of resources. Moreover, development of the class switching mechanism must be concomitant with differentiation of the various immunoglobulin isotypes (IgA, IgD, IgE, IgG, and IgM synthesized from the α , δ , ϵ , γ , and μ heavy chains, respectively). Switch without differentia-

tion is futile, while differentiation without switch will fail to properly express these genes

More complicated than the immunoglobulin heavy chain gene family are members of the hemoglobin gene families. These genes are regulated both temporally and spatially. In the human β -gene family, ϵ is expressed in the yolk sac during the first six weeks of embryonic development, while the γ genes are expressed in the fetal liver, and β/δ genes are produced in the adult bone marrow. Different members of the family have different oxygen-binding functions suited for a particular developmental stage. Hemoglobin gene switching is less well understood than immunoglobulin

class switching. Figure 5 delineates the factors discovered to date.

3. Degree of sequence homology is not a clear indicator of whether the genes are duplicates. In many cases, multiple identical copies of a gene are required for a normal cellular function, and therefore multiplicity must have been present from the beginning of the species. For example, multiple identical copies of ribosomal RNA genes (rDNA) are required for rapid production of ribosomes. In *E. coli*, deletion of one or two of the seven copies of rRNA genes results in reduced growth rate and a prolonged lag phase (Stevenson and Schmidt, 2004). In *Drosophila*, reducing the number of rRNA genes causes bobbed mutants with decreased viability (Terracol and Prudhomme, 1986). Moreover, other genes are involved in maintaining multiplicity and organization of rRNA genes. In the yeast *Saccharomyces cerevisiae*, mutation of the Sgs1 gene causes reduction of rDNA copy number and accelerates aging of the cells (Sinclair and Guarente, 1997). The human homolog of Sgs1 is the WRN gene, mutation of which causes premature aging (Werner's syndrome) (Yu, et al., 1996). Indeed, cells from Werner's syndrome patients display more rearranged rRNA genes than normal cells (Caburet et al., 2005). Like in the yeast, loss of rRNA genes in human cells has been associated with aging (Zafiroopoulos et al., 2005). Thus a certain degree of repetition of the rRNA genes appears to be essential for the viability of both prokaryotic and eukaryotic organisms. These genes appear to be created to function as a family, and organisms are endowed with other genes such as Sgs1 and WRN to maintain their copy numbers.

Because mutation invariably leads to diversification of repetitious genes, the cell must invoke some mechanisms, such as gene conversion, to maintain their homogeneity (Elder and Turner, 1995; Lewin, 2004; Polanco et al., 1998). The phenomenon is termed *concerted*

evolution by evolutionists, and the underlying mechanisms vaguely defined as “molecular drive” (Elder and Turner, 1995). Gene conversions must be biased toward one form to eliminate variations. These mechanisms only operate in certain gene families such as rRNA genes, but somehow restrained in other families such as human immunoglobulin V genes or MHC genes. It appears that some gene families are designed to be homogenous while others are designed to be diverse, and both must have existed as families from the beginning. Purifying selection keeps both categories from abnormal variations (Nei and Rooney, 2005).

4. Gene duplication causes copy number polymorphism within the same species or related species of a baramin. Clusters of homologous genes will predispose a chromosomal region to unequal crossing-over and thus cause variation in copy numbers. For example, due to the highly repetitive nature of the immunoglobulin heavy chain genes, this locus displays considerable polymorphism among the human population, depending on race. Duplications of the heavy chains genes are 22% in Mongoloids, 10% in Caucasians, and 5% in Negroids (Rabbani et al., 1996). These duplications cause no or slight elevation in serum immunoglobulin levels (Rabbani et al., 1995). Deletions are much rarer (1.5–3.5% depending on race), presumably due to negative selection.

The organization of the human immunoglobulin heavy chain gene family suggests that the segment from the I promoter of the $\gamma 3$ gene to the first 3' enhancer may have been duplicated in history, producing the downstream $\gamma 2$ - $\gamma 4$ - ϵ - $\alpha 2$ cluster and an additional 3' enhancer. Subsequently, the upstream ϵ gene pseudogenized, while the downstream γ (2 and 4) genes subfunctionalized as evidenced by their inability to activate complements or to bind Fc receptors.

The clustered rRNA and histone genes also vary in number within species (Michel et al, 2005; Thomas et al., 2000), so are the clusters of human green visual pigment genes (Nathans et al., 1986a). Deletions of visual pigment genes due to unequal crossover may cause color blindness (Nathans et al., 1986b). With recent advances in genomics, copy-number polymorphism within species is receiving increasing attention (Sebat et al, 2004; Sharp et al., 2005).

5. Duplication by transposition is normally suppressed. Transposons are mobile DNA elements that can change locations (transpose) within the genome. While some transposons are excised from their original site and inserted into another site (cut-and-paste), others are duplicated onto a new site without losing the original copy (copy-and-paste). Most bacterial transposons are not transcribed during the transposition process, while most eukaryotic transposons are retrotransposons that involve an RNA intermediate for transposition. Transposition rearranges DNA and may serve as a means of regulating gene functions. Repeated copy-and-pasting is supposed to be accountable for the production of the abundant transposon families found in many creatures, especially human and mammals.

In reality, because transposition disrupts genes at the site of insertion, it is normally strictly controlled by the host cell and kept at low levels. Transposition in bacteria has an overall rate of $\sim 10^{-3}$ – 10^{-4} per element per generation. Retrotransposition of yeast Ty elements occurs at $\sim 10^{-7}$ – 10^{-8} (Lewin, 2004, pp. 470, 501). In *Drosophila*, failure to suppress transposition of the P element induces chromosomal breaks and causes sterility (hybrid dysgenesis). A variety of mechanisms have been discovered or proposed for silencing of transposons, including DNA methylation, RNA interference, interference of splicing, heterochromatin formation, etc. (Agrawal et al,

2003; Cook and Karpen, 1994; Hashida et al, 2006; Lewin, 2004).

The vast majority of human transposons are not actively transposing. Insertion of transposons is responsible for only 0.1% of *de novo* mutations in human. However, in inbred mice, the percentage is more than 100 times higher and varies significantly between strains (Maksakova et al, 2006). Much of the discrepancy is due to the activity of a class of retrotransposon called endogenous retroviruses (ERVs). A minority of the mouse ERVs can actually produce infectious viral particles that efficiently infect the germ line (Lock et al, 1988). Not surprisingly, ERV insertions cause deleterious mutations, including carcinogenesis (Maksakova et al, 2006; Wang et al, 1997). The fact that some ERVs easily colonize the mouse genome and form gene families might be a consequence of the weakened immunity and compromised genome-stabilizing machinery due to inbreeding.

Interestingly, many human and vertebrate transposons are selectively transcribed in the germ line and in the embryo, suggesting a role of these elements in reproduction and development. Indeed, some transposons are found to encode proteins, called syncytins, essential for placental development (Dunlap et al, 2006). Others serve as regulating elements to drive tissue-specific expression of genes (see Bannert and Kurth, 2006 for review). Members of a transposon family may be regulated as a set during certain stage of development or under certain physiological situations. The human syncytin-1, encoded by an ERV, is regulated in part by an enhancer in the host sequence immediately upstream of the ERV (Prudhomme et al, 2004). The essentiality of the ERV and its collaboration with host elements suggest the ERV was designed and created *in situ* (Liu, 2006). These recent findings demonstrate that at least some transposons are not results of random transposition in history but were created

individually. At this point, we cannot rule out the possibility of generating nonessential members of transposon families by transposition.

Summary

Gene duplication is not a major means of innovation, as many contend. Duplicated genes are normally silenced and subjected to degenerative mutations. Gene families in modern genomes, at least some of them, were not created by gene duplication, although duplication may cause variations in family size. Furthermore, most gene regulation hierarchies are unique among “advanced” organisms and could not have been produced by duplication of primitive genes.

In-depth studies of copy-number polymorphisms within species will certainly shed more light on this topic. Observation of any new molecular functions in individuals with extra copies of a gene will nullify the above argument.

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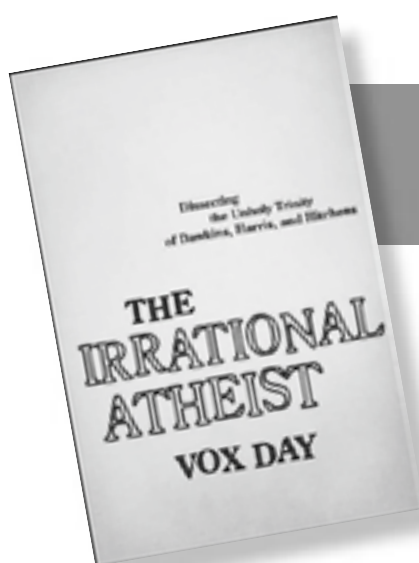
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Book Review

The Irrational Atheist

by Vox Day

Ben Bella Books, Dallas, 2008,
305 pages, \$25.00.

“The idea that he is a devotee of reason seeing through the outdated superstitions believed by less intelligent beings is the foremost conceit of the atheist” (p. 7). So starts Vox Day’s demolition job on the various publications of the “New Atheists” in recent years. Perhaps it is a mark of a healthier Christianity that the spate of these polemics has been met with a variety of theological responses (Keller, 2008). But one of the most intriguing and by far the most entertaining is the effort of the self-styled Christian libertarian blogger, Vox Day, a.k.a. Theodore Beale, entitled *The Irrational Atheist*. Aside from the irreverent humor (the book begins with the sentence, “I don’t care if you go to hell”), it is distinct in its narrow approach. The author states early on:

I’m not trying to convince you that God exists. I’m not trying to convince you to accept Jesus Christ as your Lord and Savior. I’m not even trying to convince you that religious people aren’t lunatics with low IQs who should be regarded with pity and contempt. But I am confident that I will convince you that this trio of New Atheists, this Unholy Trinity, are a collection of faux-intellectual frauds utilizing pseudo-scientific sleight of hand in order to falsely claim that religious faith is inherently dangerous and has no place in the modern world. (p. 7).

And in that narrow goal of making monkeys out of the leading lights of contemporary atheism, Day wildly exceeds his stated expectations. He begins by

distinguishing between “High Church” atheists—the average university professor fits the mold—and “Low Church” atheists, or those that live as if there is no God while not thinking much about it on the way. He professes some sympathy for the latter: “There are far worse creeds to live by than shrug and let live” (p. 23). He also quickly grasps the connection between atheism and contemporary science.

But it is impossible to separate atheism from science, because scientific materialism has such an influence on atheistic thinking even in matters where science is not directly involved. For some atheists, such as Richard Dawkins, science played an important role in causing them to abandon their former faiths but

now serves primarily as a foundation for an ongoing intellectual journey. For others, it is a religion substitute that provides them with purpose and a secular priesthood to whom they look for answers (p. 28).

But he just as quickly notes that these atheists are not so much concerned about science as they are with using it to cloak their outdated Enlightenment values—a distinction that still evades many Christians who compromise with those values because they worry about losing a Christian voice in the sciences. He also takes tongue in cheek to point out that while man has survived millennia of religious belief, he might not survive a few centuries of science, given overpopulation, global warming, etc. Of note, too, is the scientific achievement of “Christian” America, which on a per capita basis exceeds that of the more atheist France by over 28%.

But the book is not specifically about science; it is about the numerous errors of logic and reason exhibited by the new atheists. Day goes right to work on them, beginning with Sam Harris, author of *Letter to a Christian Nation* (2006). Day begins gently (for him), stating that, “Sam Harris is a grave embarrassment to atheism, intellectuals, and the Stanford University philosophy department” (p. 113). He goes on to cite a dozen factual and logical errors in detail, before zeroing in on Harris’s most popular argument that in spite of Christian morality, crime is more prevalent in cities in “Red States” (read Christian) than in “Blue States” (read atheist) in America. Day uses census data on the county level and FBI statistics to demonstrate that Harris is not only wrong but also draws conclusions exactly the opposite of what the data really show—there is a good correlation of urban crime and unbelief. As with most of his criticisms of the new atheists, Day is not content to put a stake through the heart of the argument, but he goes on to disperse the ashes of the cremated corpse on the winds of reason,

logic, and science. He does the same to Harris’s dishonest attempt to lay the genocide of modern (atheist) communist regimes off on religious belief and digs deeply enough to show that Harris does so because of his own nonrational prejudice against faith.

Day then turns to Richard Dawkins, whom he labels “Darwin’s Judas.” In his usual understated style, he begins the chapter saying, “Scientists should come with a sell by date” (p. 135), explaining that whatever positive contributions Dawkins made to science are long past. He sums up the English don’s error succinctly: “In *The God Delusion*, Richard Dawkins is using his reputation as a famous Darwinian scientist to sell a propagandistic vision that is directly opposed to that very science as well as the religions it purports to attack” (pp. 136–137). And that is Day’s contribution to combating the rants of Dawkins—pointing out that he never actually gets around to using the science that he so vigorously trumpets.

While Dawkins incessantly complains about the lack of evidence for God, he never quite gets around to explaining precisely what proof, presumably scientific, would be sufficient for him. He poses no potentially falsifiable experiment that would suffice to prove or disprove God’s existence nor does he even consider the question of whether any such experiment would conceivably be possible (p. 139).

Day goes on to provide a list of empirical hypotheticals to falsify Christianity, just to prove that it could have been easily done by Dawkins, had he any objective interest in doing so. He then goes on to list seven beliefs of Dawkins that require no less faith than religion, such as the idea that science inspires art or that Catholicism is more damaging to children than sexual abuse. Day supplies scientific evidence to refute all. Then he goes after Dawkins’s attempts at mathematics. As a computer game designer,

he is more familiar with the applicable math than Dawkins and demonstrates it in short order, once again to Dawkins’s embarrassment. Finally, after wrecking Dawkins’s “skyhook” argument that tries to circumvent the anthropic principle, Day concludes, “But if science cannot inspire great art, never let it be said that a scientist cannot inspire great comedy” (p. 158).

Next on the list of victims is Christopher Hitchens. Day damns with faint praise:

However, his book, *god is not Great*, has the virtue of being presented to the reader in a commendably honest and straightforward manner. Hitchens is not marketing humanism with a scientific brand, he is not pushing for global government under the guise of godlessness, he is merely venting about his personal hatred for religion in general and Christianity in particular (p. 161).

Day praises Hitchens’s vast experience and literary talent, but notes that “he is subject to the common journalistic misconception that the plural of anecdote is data (p. 162). In other words, Hitchens is a great storyteller but not much on logical argumentation. For example, he cannot explain why anyone should accept evolving morality as the basis for any moral judgment. He notes that Hitchens is not as upset as Dawkins about creationism, because

unlike Dawkins, Hitchens does not sell DVDs marketed to schools and libraries from his Web site, or more likely because the highly literate Hitchens recognizes that it does not matter if school children who cannot read or do arithmetic are taught that they were created by natural selection, God, or space aliens (p. 166).

Not content to let things go at that point, Day provides a table of 51 assertions made by Hitchens that are presented without supporting evidence and are often self-refuting. Then he

zeroes in on Hitchens's four big reasons for rejecting God.

If these four objections are truly the basis for Hitchens' hostility toward God and religion, then the irrepressible atheist may be much closer to returning to the faith of his fathers than anyone suspects, because one of these objections is trivial, one is irrelevant, and the other two are simply wrong (p. 173).

Next on the menu is Daniel Dennett, the author of *Breaking the Spell* (2007) and *Darwin's Dangerous Idea* (1995). Day begins by apologizing for lumping him with the others but then proceeds to illustrate a series of logical errors that lead one to conclude that he is going easier on Dennett only because he is more civil than Dawkins and more thoughtful than Harris.

The occasional logical errors and assertions in the face of evidence such as these show that while *Breaking the Spell* is unquestionably superior in almost every way to the Unholy Trinity's four books on religion, the scientific-sounding speculation that fills it is nothing more than that, speculation. The literary editor of *The New Republic* underlined this point in an utterly brutal review of the book that appeared in the *New York Times*, reminding the reader that at the end of the day, *Breaking the Spell* is not science, but a book of speculative philosophy written by a science fetishist (p. 186).

But Day, in the end, offers praise for Dennett's offer of a rapprochement of inquiry into the truth of both science and religion, claiming that no serious Christian can refuse that offer, nor should one be afraid of searching for truth in God's world.

After finishing with Dennett, Day turns his guns on Michael Onfray, a radical French philosopher who is as well known in Europe as he is unknown in America. Day starts gently: "Like so many French philosophers of the recent

past, Onfray's primary use for Occam's razor is to repeatedly slash his own throat" (p. 198). But despite the fact that his book, *Treatise on Atheology* (2005), was panned by an Italian reviewer, who said, "I don't know if the idea is more silly or ignorant," Day appreciates Onfray's honesty.

Onfray performs the invaluable task of demonstrating that atheism possesses the inherent potential to be every bit as unrepentantly evil by traditional Western moral standards as Christians have always believed it to be.... For Michel Onfray demands nothing less than an atheological *auto da fé*, burning Western civilization on the fiery stake of a New Luciferian Enlightenment. This would not be worrisome if it were only more inane insanity on the part of a French philosopher, the problem is that Onfray's proposed new order is not merely the logical extension of the secular utopia sought by Russell, Dawkins, and Harris, it is the stark rational articulation of that which the New Atheists do not dare to admit, either to themselves or to the reading public (pp. 199, 207).

That is because Onfray detests Christian values as much as Christian religion, selectively ignoring the terrors of modern atheism while blaming all of society's ills on the Catholic Church. Generally, it sounds as though the philosopher has more than a few loose screws.

According to Onfray, the New Atheist path leads only to Nietzschean nihilism: his *Atheology* is post-Nietzschean, leading humanity beyond the dialectic of nihilistic struggle and into a hedonistic philosopher's paradise (p. 206).

After dealing with the exponents of the new atheism, Day tackles some of the traditional accusations against Christianity, including the Inquisition, the Crusades, Hitler-was-a-closet-Christian, etc. He deftly turns the argument around, displaying knowledge of military

history and history in general that the atheists seem to have missed in their zeal for science. In his chapter, "The Red Hand of Atheism," Day documents, in more detail than needed, the evils that seem to crop up whenever atheism takes root. Following up, he briefly refutes ten common arguments used by atheists today.

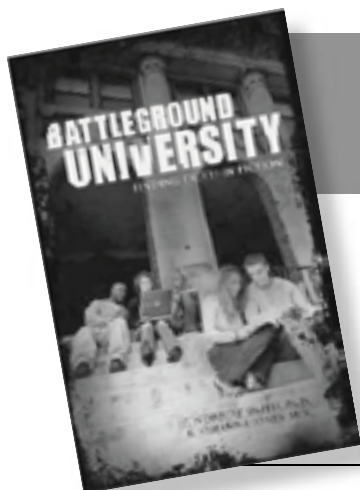
Despite some theological arguments that can be settled over a beer in heaven (or whatever we'll be drinking there), Day's book is a solid logical and scientific refutation of those who extol themselves as exponents of science and reason. That is its greatest strength—intellectual judo at its finest. Of course, the chuckle-per-page writing style doesn't hurt either. Although some see atheism, old or new, as being tangential to arguments about origins, it is at the core of the various forms of Enlightenment science and post-Enlightenment philosophy that we fight on a regular basis. It doesn't hurt either that Day offers the book on his blogspot as a free pdf download. I heartily recommend it.

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Book Review



Battleground University: Finding Truth in Fiction

by E. Norbert Smith
and Johanna Jones

Tate Publishing, Mustang, OK,
2008, 134 pages, \$12.00.

Employing the style of C. S. Lewis's classic, *The Screwtape Letters*, the authors reveal a not-so-subtle shift in collegiate educational techniques and course content from true critical thinking to brainwashing students with godlessness. Major tools in the satanic arsenal are overemphasis on the reliability of the scientific method, the "truth" of evolutionary origins, political correctness, and the use of the seedier products and ideas from modern media in the classroom. The authors' website is www.GodofCreation.com.

The contents of this tongue-in-cheek satire consist mainly of 17 letters of advice and guidance from chairdemon Ian Sidious to two professors at the fictitious Battleground University. The recipients are Mel Volent of the Biology Department and Peri Fidious of the Department of Critical Thinking Studies. The topics covered in these letters are amazingly diverse, detailing many of the spiritually and morally destructive concepts in seemingly innocent topics.

The chairdemon urges his human followers to promote philosophic naturalism, encourage self-centeredness, crusade against morality, and discourage true thinking (ignorance is bliss). Christians are targeted as judgmental,

intolerant, conservative, traditional, white, and consumerist. *Ad hominem* attacks and stereotyping are quite effective. The main attack should be aimed at destroying Christianity at all costs. Faith in anything beats faith in God. Absolutely neutralize any Christians in the class. Suggest the advantages of drug-induced "spiritual meditation" to empower the mind.

Ian Sidious admits that the lack of evidence supporting evolution is genuine, but it has been successfully concealed. He advises his pupils to belittle creationism and intelligent design. One of the great demonic triumphs is the teaching of evolution in Christian universities as God's method of creation.

The book's foreword by Fritz R. Ward explains the shift in emphasis in undergraduate education. He notes the deification of science and its misapplication in many academic subjects. An afterword finds Professor Mel Volent in horrifying circumstances after a lethal overdose of drugs during his customary evening "spiritual meditation." I recommend this thoughtful satire by two college professors as an eye-opening account of trends in modern academia.

Lest any reader think this book is far-fetched, I offer two recent occurrences

about which I know. A Christian young man registered in an English class in a state junior college. On the first day of class, the instructor informed the students that he would teach English using pornographic films. He suggested that anyone who would be offended should drop the course. This student followed his advice. A Christian young lady at a state college was in a class where the teacher gave assignments involving immoral acts, i.e., have a sexual (homosexual) experience with a member of the same sex and write a report on it. The girl, not performing the acts, was subject to a scathing rebuke by the instructor. A legal institute that defends Christians was contacted. They, in turn, contacted the university administration. The problem was resolved, and the student was vindicated.

For we do not wrestle against flesh and blood, but against principalities, against powers, against the rulers of the darkness of this age, against spiritual hosts of wickedness in the heavenly places (Ephesians 6:12 NKJV).

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A New Report of Unique Features in the Peristome of *Funaria hygrometrica*

A Van Andel Creation Research Center SEM Study

Mark H. Armitage*

Abstract

Sporophyte capsule structures of the moss genus *Funaria* from California were studied under Scanning Electron Microscopy. The peristome of the sporangium was observed to have a unique “pad” and “web” bellows that appears to be little reported in the literature. This pad and web structure functions, along with the peristome teeth, as a tiny bellows assembly that sucks minute numbers of spores out from the capsule for dispersion during optimum conditions for spore distribution. This bellows system appears to have been skillfully designed. I conclude that such design is a result of divine intelligence.

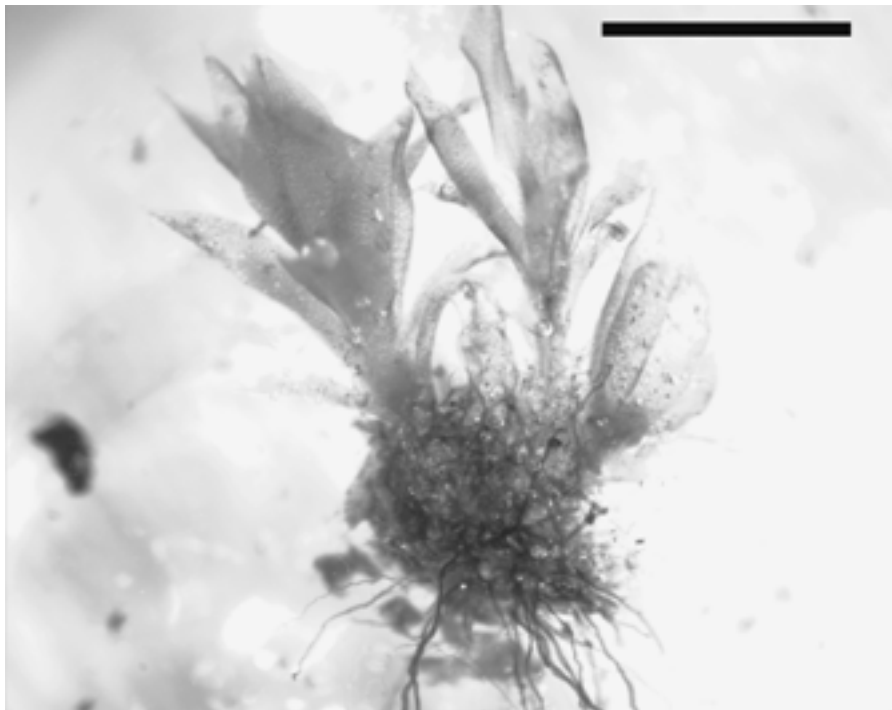


Figure 1. Light micrograph, individual fresh moss specimen complete with root ball. Scale bar = 0.5mm. The leaflike structures here are phyllids, part of the gametophyte generation from which the sporophyte emerges.

Introduction

Moss plants (Figures 1 and 2) and their spore producing bodies (sporangia, [singular, sporangium], see Figures 3 and 4), have been of great interest for many decades. Mosses that have economic value include *Sphagnum*, which is used in the floral industry to line floral arrangement baskets for water retention, as a low-grade fuel, as packing material for shipping bare-rooted plants, and as an amendment to soil for water retention. They are, however, at the focus of

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Figure 2 (*left*). SEM micrograph, dehydrated moss. Note extensive root system. This is the gametophyte. Scale bar = 0.5mm.

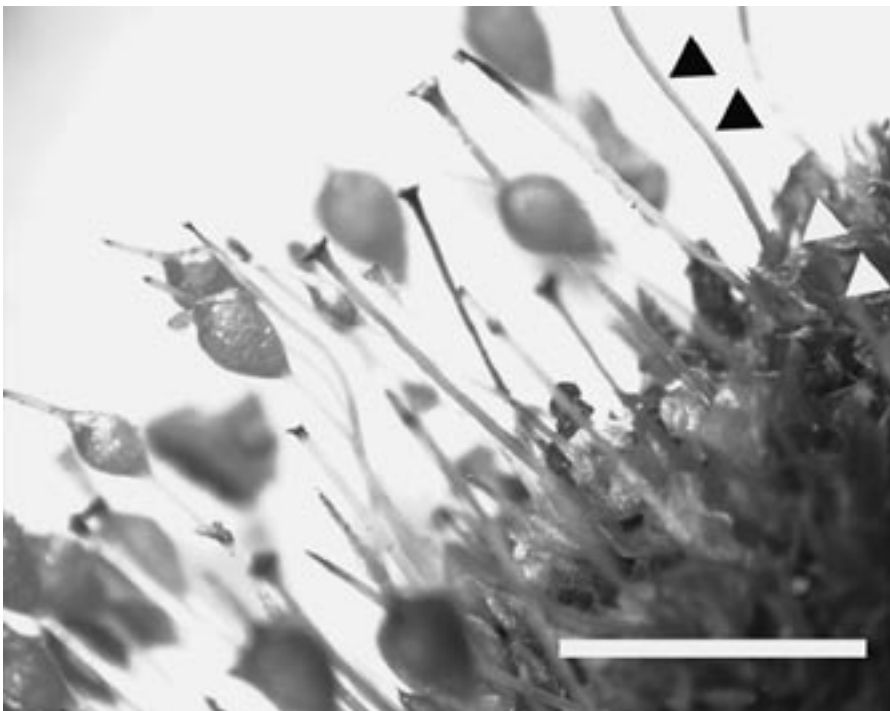


Figure 3 (*below left*). Light micrograph, moss gametophyte generation (white arrow heads) supporting vertical sporophyte generation (black arrow heads). Scale bar = 2.0 cm.

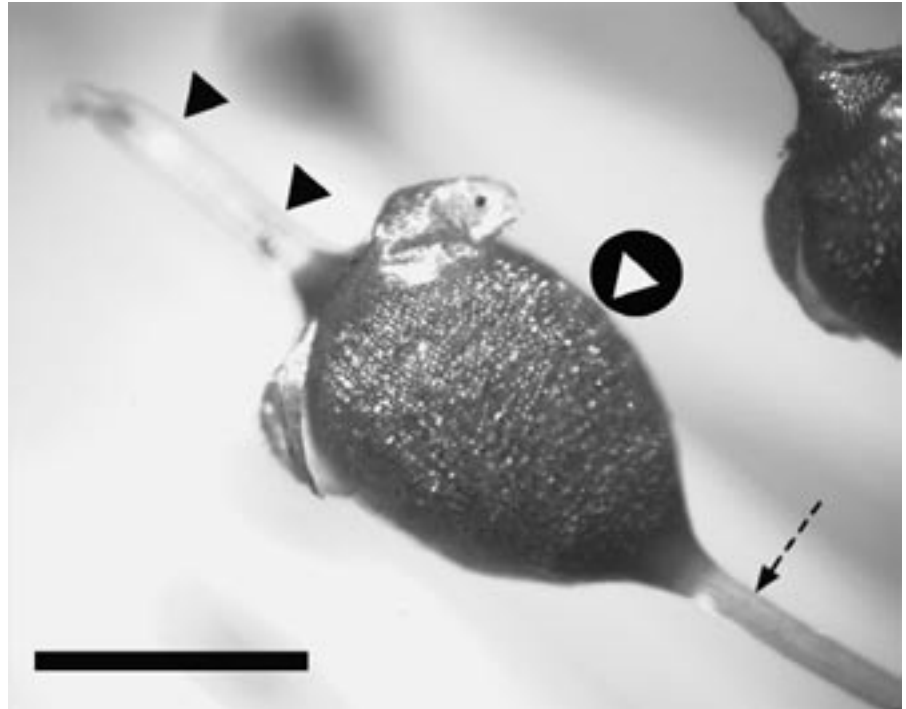
the ongoing intense debate among evolutionists as to which were “the earliest divergent land plants” (Wellman et al., 2003, p. 284), and in that sense, mosses are very important.

Most, but not all, mosses possess a specialized, tooth-like structure within the sporangium called a peristome (see Figure 5), which circumscribes the inner opening of the sporangium and is integral for the timely dispersal of spores into the surrounding environment. Peristome teeth are usually hygroscopic, thus, in response to changes in humidity, they will flex back and forth within the sporangium. This has the effect of catapulting tiny spores from the spore capsule to be carried away by the wind.

Several early workers, most notably in France and Germany, carefully described these sporangial capsules and their peristome teeth as early as the mid to late 1800’s (Berkshire, 1863, Bescherelle, 1885; Hutton 1874; and Philibert, 1888). One early worker even showed how stages of the life cycle differ remarkably from each other in water absorption mechanisms (Vaizey, 1887). Vaizey did not describe the peristome from the

Figure 4 (right). Light micrograph, of the upper portion of *Funaria* sporophyte. This is a close up of the seta or stalk (black dotted arrow), sporangium (white arrowhead), and calyptra covering (black arrowheads). Scale bar = 1.5 mm.

Figure 5 (below right). SEM micrograph, moss sporangium with uncovered peristome teeth. Note several teeth ripped away from the place where they were attached to the central pad. Dotted scale bar = 250 micrometers.



mosses he studied. Hutton provided drawings of the various types of sporangia found in New Zealand and stated that for the one group he studied, the peristome teeth were touching at their pointed tips. Thus, they were touching or interlaced, so as to form a cage-like structure over the mouth, allowing the spores to be gradually blown away in small numbers (and strictly by high winds) (e.g. Hutton, 1874, p. 345). Thus, in this instance, the peristome functions as little more than a passive cage. With respect to another variety of moss, Hutton (1874) stated, “of the genus *Funaria*...[in] this moss, the peristome is double, the points of the teeth of the outer one, being connected by a disc, which in time falls away,” (p. 346), although this “disc” structure was not featured in any of his figures. However, Hutton (1874) did not discuss the structure of this disc, nor the functions it performed.

Some workers have conducted scanning electron microscope (SEM) studies of the peristome teeth (Anderson and Palmer, 1982; Gallego et al., 2004; Huttunen, 2004; and Konopka et al., 1998). This lack of research is puzzling



since the peristome teeth may be essential for the classification of mosses. Electron micrographs could assist in the taxonomic diagnosis of these minute plants. Anderson and Palmer (1982), Gallego et al. (2004), Huttunen (2004), and Konopka et al. (1998) all displayed high magnification images of peristome teeth but did not discuss or illustrate a “disc” or web connecting the teeth one to each other. Nor did Troughton and Sampson (1973) mention this structure in their plant kingdom SEM survey, even though they supplied two photos of the peristome (pp. 48 & 49). A fascinating set of SEM micrographs of moss sporophyte images (including peristome teeth) is found online at: <http://www.botany.ubc.ca/bryophyte/index.html> (accessed on 12/26/07).

The peristome teeth and the sporophyte capsule are often illustrated by many authors, (Ignatova, et al., 2003; Munoz, 1999; Ochyra, 1999), but no such disc or connection between teeth tips is discussed or illustrated. One SEM photo of a central disk connecting the peristome teeth, resembling Figure 6 of this paper, was published by Richardson (1981, p. 74), yet his observation of the workings of the bellows system of spore dispersal was incomplete. With respect to spore dispersal, Richardson (1981) merely stated, “the stalk twists or untwists (under moist conditions) so that the capsule rotates quite rapidly” (p.74). The web structure was described as “a central plate of cells” and as “a small white central disk” (Richardson, 1981, p. 73 & 74), yet no undulation of the bellows system was described.

The present research used the SEM to study the elegantly complex design of the moss peristome mechanism and the amazing process by which spores are ejected from the capsule.

Materials and Methods

Colonies of fresh moss *Funaria hygrometrica* Hedw. were collected from under a



Figure 6. SEM micrograph, moss sporangium with uncovered peristome teeth. Note that all the teeth are attached to the central pad. The peristome teeth and the pad form the web. Dotted scale bar = 176 micrometers.

perennial shade-casting bush in a well-kept lawn in Covina, CA during the spring of 2007. Specimens were placed in an open plastic dish and were kept in the shade within a greenhouse where they were watered daily. When individual plants were selected for microscopy, the dish was placed on the base of a Carl Zeiss GSZ dissecting microscope (Jena, Germany) outfitted with a fluorescent ring-light illuminator. Individual plants were removed with fine forceps under 10X magnification and immersed in cold, 2% buffered glutaraldehyde for fixation.

Plants were processed for SEM according to the protocol outlined by Armitage and Howe (2004). Optical photographs were captured with a DVC digital camera and EPIX/PIXCI image capture board. SEM images were captured with a Hitachi S-2400 SEM employing standard and backscattered electron imaging (housed at the Van Andel Creation Research Center, Chino Valley, AZ). Figure 7 was obtained using a new Hitachi S-3600 “wet-SEM” (environmental microscope) to photograph living, unprocessed moss sporangia.

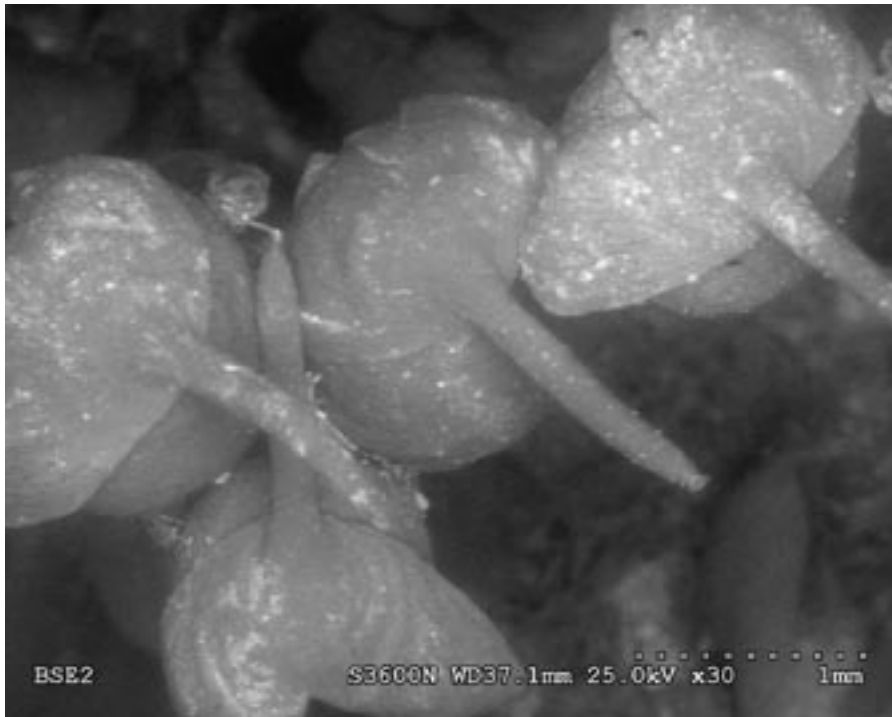
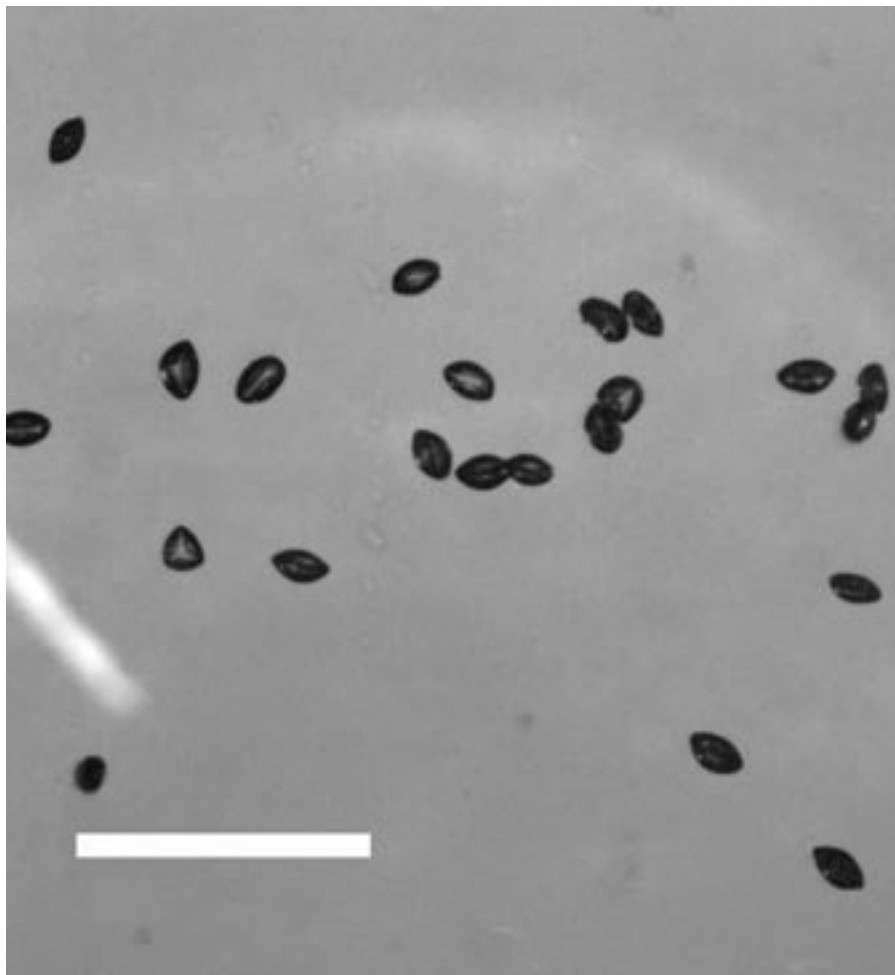


Figure 7 (*left*). Backscattered electron SEM image (photographed on a new Hitachi S3600 “wet SEM” microscope.) Note pointed ends of the four calyptra loosely attached to each sporangia. This is a view from the top, looking down on the calyptra. Dotted Scale bar = 1 mm.

Figure 8 (*below left*). Light micrograph, individual moss spores. The spores are pulled out of the sporangium by the pumping action of the web mechanism. Scale bar = 90 micrometers.



Results and Discussion

The sporangia of *Funaria hygrometrica* are 1–2 mm in length. They have a sausage-shaped container at the apical end of the stalk called seta (plural, setae). The stalk and capsule are part of the sporophyte generation and are attached to the gametophyte (see Figures 3 and 4). These capsules produce spores (Figure 8) and then disperse them in a unique fashion. If conditions are suitable, the spores are released and then germinate forming a new gametophyte generation. For an excellent illustration of the entire life cycle of this plant see Bergman (1998).

As the sporangium matures, it grows upward from the gametophyte to a height of about 1–2 cm. The developing capsule can be seen covered by a tiny calyptra which resembles a “witches’ hat” (see Figures 4 and 7). Once the sporangium has reached full size, the calyptra is shed making the operculum visible (Figures 9, 10, and 11). The operculum is sometimes shaped like a saucer stretching over the capsule opening. On other opercula, it resembles a



Figure 9. SEM micrograph, moss sporangium. Note pointed operculum (white arrow). The difference in operculum shape between specimens (Figures 9 and 10), might be due to genetic differences. Scale bar = 0.75 mm.

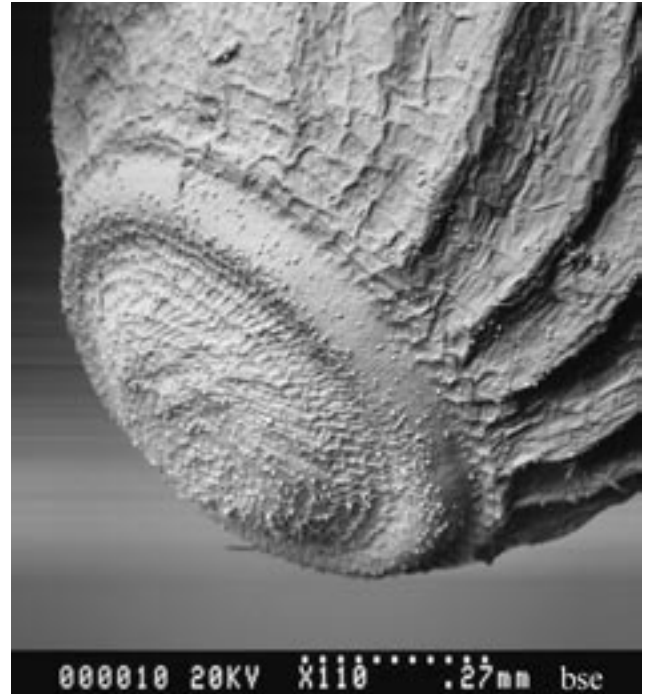


Figure 11. Backscattered electron SEM image, sporangium operculum. Scale bar = 0.27 mm.



Figure 10. Backscattered electron SEM image. Note two sporangia with saucer-shaped opercula (white arrows). The sporangium at the right was squashed during processing. Dotted Scale bar = 0.75 mm.

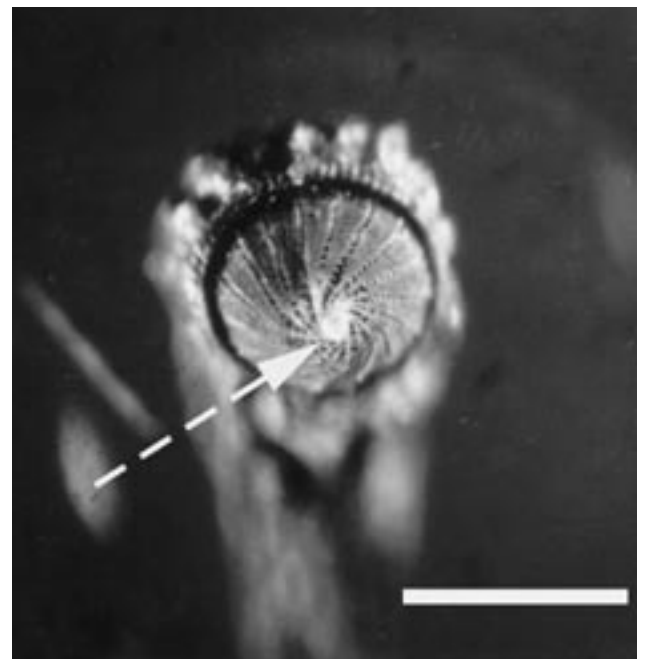


Figure 12. Light micrograph, showing the peristome teeth and the central pad which together form the web. The white arrow points to the white pad at the center of the web. Both the calyptra and the operculum are missing so one is looking directly down at the web. Scale bar = 1.25 mm.

pointed hat (Figure 9). The difference in shape between the two calyptras seen in Figures 9 and 10 may be due to genetic variations.

The sporangium tips over and faces downward, which may prevent mist or dew from entering the capsule and jeopardizing the prompt dispersal of its spore cargo. When the relative humidity is favorable, the operculum falls off, revealing the tightly wound spiral of peristome teeth (Figure 12). These teeth then slowly unwind and open, to some extent.

1. The tip of each peristome tooth is bound by a thin, flexible connection to a pad-like structure that is positioned at the opened center, (Figures 6, 12 and 13).
2. The peristome teeth join to the pad forming a "web."
3. Attached to the pad, the peristome teeth are held in a certain conformation. As the peristome desiccates, this pad and web system stretches, allowing further opening of the peristome teeth. When the teeth become spread apart evenly and stand perpendicular to the annular ring, which surrounds the peristome, they are bound tightly to the pad and they produce the web.
4. Figure 13 provides a view of the peristome teeth attached to the central pad.
5. Upon further desiccation, a fascinating process allows the release and spread of spores. Air currents pass over the dilated peristome and cause the web with its center pad to oscillate repeatedly in and out of the spore filled sporangium in an undulating fashion, much like the pumping of a bellows or a fluttering parachute. This was observed repeatedly with many different sporangia employing the dissecting microscope equipped with a fiber-optic illuminator. As a result of this undulation of the web, I observed

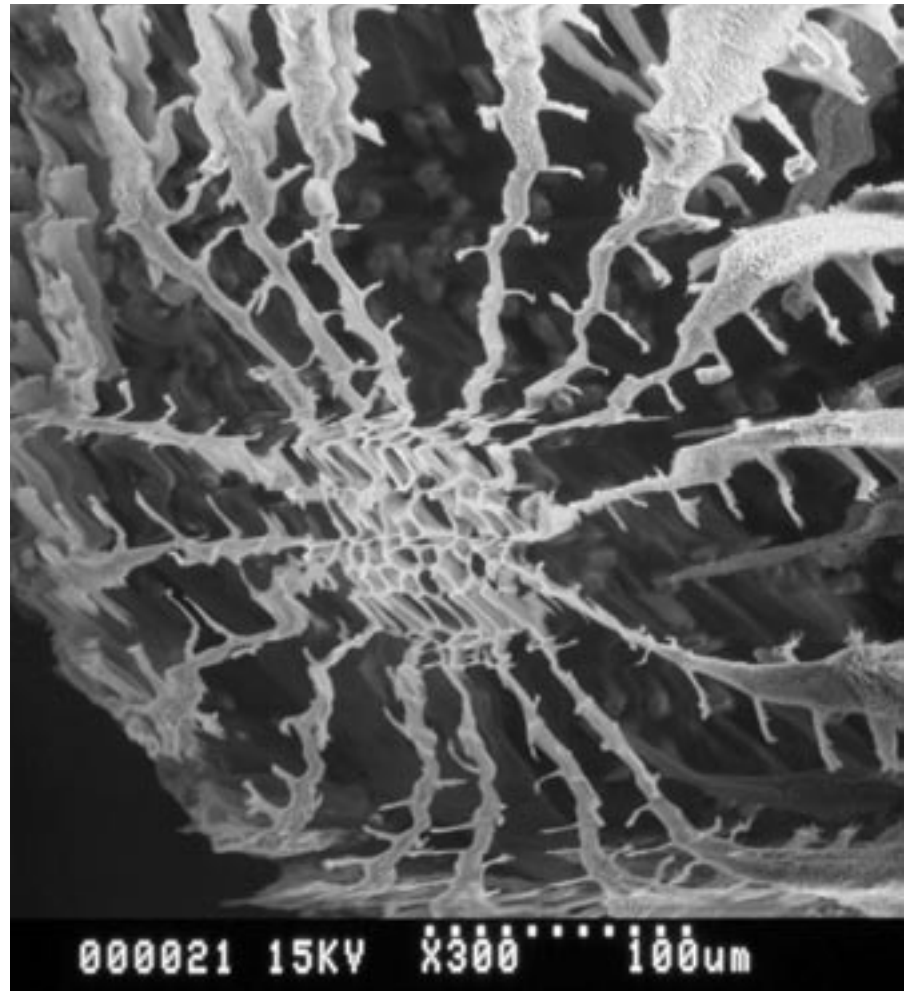


Figure 13. SEM micrograph, moss sporangium showing the web mechanism. Note depressions and other structural detail visible in the central pad. Dotted scale bar = 100 micrometers.

6. Although some of the peristome teeth are shown disconnected from the pad in Figures 5 and 14, this is not normally the case. The operculum was inadvertently mechanically removed in these individual sporangia, which resulted in tearing the pad from the teeth.
7. This web and pad structure serves several purposes, and appears to have been skillfully designed:
 - a. Spores are kept safe and dry in an enclosed, protected, downward-facing environment and the peristome keeps them from falling out.
 - b. The peristome provides a physical barrier to prevent the entrance of insects.
 - c. Only when conditions are favorable for spore dispersal are spores released by the repeated pumping action of the web and center pad.



Figure 14. SEM micrograph, moss sporangium with uncovered peristome teeth. Note several teeth ripped away from their previous position on the central pad. Dotted scale bar = 100 micrometers.



Figure 15. SEM micrograph, moss sporangium with uncovered peristome teeth. Note the detail visible on the edges of the peristome teeth. Dotted scale bar = 50 micrometers.

- d. Only a small portion of total spore production is released at a given time, when air currents can carry them some distance.

The arrangement, quantity, and size of the peristome teeth have been used as a diagnostic character in determining the “relatedness” or taxonomy of different mosses (Goffinet, et al., 1999). In addition other features such as the appendages on the peristome teeth (shown in Figure 15) can be used for taxonomic purposes. Of late, however, many botanists have been studying and comparing the nucleotide sequences of these plants for this purpose. This has led to some major reversals in the historical taxonomic scheme, because the DNA sequence comparisons do not result in a moss taxonomic scheme that is consistent with a morphology-based

taxonomy (Goffinet et al., 2001 and Budke et al., 2007). Moreover, throughout the putative “fossil record,” moss sporangia and their peristome teeth are identical to modern observed living specimens. Intact peristome teeth and capsules have even been found in moss specimens buried in volcanic tephra (ash) in layers purported to be over 25,000 years old (Zazula et al., 2006), yet they are identical with contemporary specimens. Furthermore, recent creationist work in radiometric dating (Vardiman et al., 2005) has shown these dates are suspect and probably subject to gross error.

Conclusion

The sporangia of *Funaria hygrometrica*, with their associated peristome teeth are

a remarkably well-engineered system by which an orderly and timely release of spores occurs. Future work will focus on the various stages of the moss life cycle with special attention given to features of these interesting organisms that demonstrate the design features endowed to them by the Creator. It would also be important to determine if there exists a web mechanism in other species of mosses.

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Reports of Living Pterosaurs in the Southwest Pacific

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Abstract

Standard models of evolution assert that all species of dinosaurs and pterosaurs became extinct long ago and that their fossils are evidence for unlimited common ancestry, the extinction of the vast majority of species opening the way for those more fit to survive. Although all species of pterosaurs could have been destroyed by the Flood and post-Flood changes, the young-earth view holds out the possibility of extant pterosaurs. Investigations of reports of creatures whose descriptions suggest Rhamphorhynchoid pterosaurs in remote areas of Papua New Guinea were carried out between 1994 and 2007. Two expeditions to Umboi Island in 2004 resulted in formal interviews with villagers, and an expedition deep into the interior of the mainland in 2006 resulted in indirect video evidence and a sighting by two native explorers. Although no direct proof has been presented, the indirect evidence is substantial and intriguing.

Introduction

Pterosaur fossils were first discovered in Germany in 1784. By Darwin's time, pterosaurs were all assumed to be extinct. Paleontological expeditions gathered evidence of the deep past, since evolution negated the possibility of extant pterosaurs. That assumption (along with the belief that natural history must be interpreted by scientific naturalism) caused old human records of "dragons" to be relegated to the status of myth

(Woetzel, 2006a). But what if those accounts contained a germ of truth? In that case, accounts of flying dragons may come from actual sightings of pterosaurs, and some species might have survived into the present.

The search for living pterosaurs is cryptozoological. Cryptozoology is the study of "hidden" or "unclassified" zoological species or possible species, especially in the early discovery stages. A number of expeditions in recent years

have collected and analyzed eyewitness testimony, primarily in Papua New Guinea (PNG) (Figure 1). These accounts center on a strange creature the natives of Umboi Island (Figure 2) call a "ropen." In addition to interviews (from 1994 through 2004) with PNG natives, interviews with five Western eyewitnesses were conducted (from 2004 through 2007) by e-mail, telephone, mail, and in person.

Following publication of the book *Searching for Ropens* in mid-2006, Paul Nation's late-2006 expedition resulted in video evidence of what is believed to be bioluminescence of an unidentified flying creature. This interested the producers of *Destination Truth* on

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Figure 1. Map of Papua New Guinea. Tawa Village = 1; Salamaua = 2; Finschhafen = 3; Umboi Island = 4; New Britain = 5; Bougainville Island = 6; Manus Island = 7.

the Sci-Fi Channel enough that they mounted a video expedition in early 2007 that recorded another instance of this unidentified light. Thanks to the broadcast of that episode in mid-2007, the public has been exposed to the possibility of living pterosaurs.

A body of indirect evidence has accumulated that suggests that extant pterosaurs exist in the southwest Pacific area. This paper will present and evaluate that evidence and address some of the skepticism of the possibility of extant pterosaurs, suggesting that this skepticism tends to rest on an evolutionary worldview.

Eyewitness Accounts

Eyewitness testimonies can be divided into two categories: those describing a flying light and those describing a creature. Four of the eyewitnesses describe both a glow and a shape or features, connecting the two types of description.

Most ropen sightings are of a bright but brief glow that moves approximately horizontally at about 330 ft (100

m) above ground level, often against a mountain background. Based on interviews from the 2004 expeditions (Tables I and II), an estimated several hundred Umboi Islanders have seen this light. This is not conclusive of living pterosaurs but is strong evidence of an unknown flying creature, probably displaying bioluminescence. Of the nine American expeditions (1994–2007), six resulted in at least one sighting of the light.

While both ropen lights and meteors are fast-moving flashes of lights in the sky, several characteristics distinguish them (Whitcomb, 2007). For example, Abram of Opai Village, Umboi Island, described a ropen light that flew down to a reef and stayed at or near the surface of the sea before flying back toward Mount Bel (Whitcomb interview) (Figure 2). Another villager provided an independent account of a similar incident (Guessman-Woetzel interview) on Northern Umboi. Woetzel (2006a) sighted a large, glowing object at least 20% the apparent size of a full moon. It lacked a meteor trail and was moving



Figure 2. Map of Umboi Island. Sightings over reefs = A, B, C, D. Major peaks: Mt. Tolo (Lake Pung) = 1; Mt. Barik = 2; Mt. Sual = 3; Mt. Bel = 4. Villages: Tarawe = 5; Gomlongon (near Opai) = 6; Lab Lab = 7; Kam-palap = 8

toward Lake Pung, where other eyewitnesses had described a large, flying, featherless, long-tailed creature years earlier. Analysis of 2004-expedition records suggest that many suspected ropen lights move away from Mount Bel early at night but toward it late at night.

Daylight sightings, when eyewitnesses can better discern shape and features (Figures 3 and 4), are rare but have been documented. Eyewitnesses include an American soldier and an Australian who works at a medical university in China. An Australian couple saw a creature early at night, but ground lighting from a nearby stadium illuminated some detail. Further testimony has been collected from three natives who made daylight sightings at a crater lake, and from another native, Jonah Jim, who made a close-up night sighting just south of that lake (Figure 5).

Jonah Jim and Jonathan Ragú, both of Umboi, made separate sightings in different areas of Umboi. However, both described a glowing, flying creature. When shown many illustrated silhouettes of birds, bats, and pterosaurs,

Table I. Investigation Results.

Source	Ref	Early investigations by missionary Jim Blume (70+ interviews)
native(s)	...	West of Finschhafen, man was attacked, carried into the air, dropped, and killed
native(s)	...	In some areas, wingspans are 20 ft; on Manus Island, wingspans are 3–4 ft
native(s)	...	bat-like wings and tails with flanges and a structure on head; they glow at night

Source	Ref	1994, 1996, and 2001 expeditions
Baugh, Carl	...	Impression in sand correlates with accounts: ropens sometimes sleep on beaches
Blume, Jim	16	Sighting supports native accounts: glowing creatures much larger than fireflies
Eunice	11	The ropen can be attracted to a funeral gathering, but noise can keep it away
hunters (two)	...	Ropen can hold itself upright while on a tree trunk, like a man climbing a coconut tree
Koro, Gideon	12	At least one ropen is much larger than any bat; it can fly in daylight
man, young	...	Creatures (like magazine picture of pterosaur) bigger than a man; they eat fish
native	...	Large skinny flying creature (glowing) robbed a human grave
native	...	Man died after waking a flying creature on the beach of a small island
tradition	...	The ropen has been compared to a human; see “hunters (two)” above
tradition	...	Ropens were robbing human graves in the past; see Michael, below
tradition	...	Native says that ropen lives on mountain but comes down to hunt game
tradition	...	Ropen lives in a cave on Mount Bel
tradition	...	“Glikioik” is size of cassowary but flies; leaves burn marks on trees
tradition	...	Glikioiks arrive near Bitoi Village seasonally or on occasion
uncle of victim	9	Young boy was attacked by a glikioik and died before arriving at a clinic
woman, young	...	Flights are not confined to central & western Umboi: One flew over Lab Lab (east)

both chose the *Sordes Pilosus*, a Rhamphorhynchoid pterosaur as best fitting what they had seen (Woetzel-Guessman expedition). Baptist minister Jacob Kepas also described a glowing, flying creature. Some witnesses have compared the glow of ropens to the red glow of burning embers.

Expeditions

In 1994, Carl Baugh, Jim Blume, and Paul Nation interviewed villagers on Umboi Island, PNG (Tables I and III). They reported a glowing, nocturnal flying creature that they called “ropen.” Kuban (2007) suggests that rather than “ropen” being a pterosaur, it is likely a

creature such as a bat. However, villagers have another term for the flying fox fruit bat—“byung” (Whitcomb, 2007). In 1996, Baugh and Blume searched for the creatures in the Manus Island area (Figure 1). These two expeditions resulted in two indistinct sightings of what may have been ropens. In 2002, Nation returned to Umboi but obtained no further evidence.

After reviewing videotapes from these expeditions, I traveled, in late 2004, to south-central Umboi Island (Figure 2) to interview villagers there. A few days after my return, David Woetzel and Garth Guessman traveled to north-central Umboi. Their interviews provided information on the tail movement of

the ropen (Woetzel, 2006a; Wellnhofer, 1991) (Figure 6) and one description that suggests a structure at the end of the tail (Whitcomb, 2007) similar to that found on fossil Rhamphorhynchoids. Information also was obtained about what we believe is bioluminescence emitted by the creature. Both 2004 expeditions included interviews designed to avoid leading the witnesses and to elicit answers revealing sighting experience rather than interviewer bias. Witness accounts provided data about the nocturnal sightings and flight headings of the creatures. There were two separate distant sightings of “ropen” lights, one by Woetzel and one by my interpreter, Luke Kenda; both sightings

Table I. Investigation Results (continued).

Source	Ref	2002 and both 2004 expeditions
Amboi, Robin	31	When it flies close, ropen light can terrify villagers; it's like a "big torch"
Batsima	22	Ropen was unafraid of landing on a tree near Tarawe Village; light was very bright
fisherman	...	Ropen flies to a reef near Kampalap (NE Umboi) once a month; see Gima, W.
Gibson	...	Ropen never glows longer than 5–6 seconds at a time (north coast) see Gima, W.
Gibson	...	A shooting star is much dimmer than ropen and much higher in the sky; see Woetzel
Gima, W.	36	Bright light over a reef lasted about five seconds (Northern Umboi Island); see Moke
Jim, Jonah	20	The ropen may be similar to a <i>Sordes Pilosus</i> (but ropen is large); see Ragu, J.
Kepas, Jacob	5	"Seklo-bali" in Wau area is like the ropen of Umboi: it glows while it flies
Koro, Gideon	12	Tail length is 7 m; mouth "like a crocodile"; color, brown; can fly in daylight; see Mesa
man, old	18	At a beach, flew fast with feet folded under a straight tail; bright light at end of tail
man, old	18	May be similar to a <i>Dimorphodon</i> but the ropen has a horn on its head
Mesa-Wesley	13–14	Has a long tail with a "diamond" — Seven boys, terrified, ran home (from Lake Pung)
Michael (Opai)	2	Glowing ropen took a human body (from a grave in Gomlongon) to Mount Bel
Moke, D.	33	Bright light over a reef lasted about five seconds (SW of Umboi); see Gibson
Moke, D.	33	Fish are attracted to light at night (Umboi fishermen use waterproof flashlight)
native	...	Fishermen tried (failed) to catch a ropen *sleeping on a beach; *see Baugh (above)
native	...	Ropen used to rob human graves but does not do this any more
Ragu, J.	34	At least one glowing ropen may fly between Umboi and Tolokiwa (islands)
Ragu, J.		The ropen may be similar to a <i>Sordes Pilosus</i> (but ropen is large); see Jim, Jonah
tradition	...	Ropen tail stiff except where it connects to body (northern Umboi Island)
various	var	Ropen lights regularly fly over northern, central, and southern Umboi Island
Woetzel, D.		Ropen differs from a meteor: no tail, angular size of 20%-25% of a full moon
Woetzel, D.	...	Large, empty clam shells correlate with a native account: the ropen eats clams

Source	Ref	2006 and both 2007 expeditions
native	...	Creature (indava?) in Tawa area was seen to be as big as an "airplane"
native	...	Indavas used to steal animals or children from Tawa (until people made noise)
Joseph+	47	Winged creature sleeping on cliff may have been an indava videotaped by Nation
Nation	44	"indava" lights seen in the Tawa village area of mainland PNG
Nation	45	Paul Nation videotaped two indava lights that were on a nearby ridge
Nation	49	True indava lights differ from distant car headlights
native	48	Light videotaped by Destination Truth was said to be the pterosaur-like creature

were consistent with ropen-light descriptions: nearly horizontal movement at low elevations (Table II).

Late in 2006, Nation witnessed a number of lights near Tawa Village (Whitcomb, 2007) in a remote moun-

tainous area of the mainland interior, where natives call the lights "indava" (Table III). He videotaped two of the

Table II. Sighting Descriptions.

Ref.	Location	Year	Eyewitness	Description	Distance	Map-1	Map-2
1	Finschhafen	1944	Hodgkinson	giant, long beak & tail, head append.	50 meters	3	
2	Umboi	1949	Michael	glowing creature attacked a grave	unknown	4	6
3	Bougainville	1971	Hennessy	long beak, long tail, head appendage	75 meters	6	
4	Umboi	1972	Cottingham	gov't official sees light fly near Lab Lab	unknown	4	7
5	Wau area	~1984	Kepas	“seklo-bali” glowing as it flew	unknown	~1	
6	Umboi	1985	old woman	it flew from mountains towards beach	unknown	4	~A
7	Umboi	unkwn	2 hunters	upright, it holds onto a tree trunk	unknown	4	
8	Umboi	unkwn	young man	pterosaur appearance; they eat fish	unknown	4	
9	Bitoi Valley	unkwn	old man	child killed by flying creature	unknown	~1	
10	Umboi	1992	John Lapu	flying light over Gomlongon area	unknown	4	6
11	Umboi	1993	Eunice	creature flew with glowing red tail	unknown	4	~B
12	Umboi	1994	Gideon K	giant ropen over Lake Pung; long tail	unknown	4	1
13	Umboi	1994	Wesley K	ropen, “too big,” had diamond on tail	unknown	4	1
14	Umboi	1994	Mesa A	ropen had a “diamond” on its tail	unknown	4	1
15	Umboi	1997	Jefron A	light flew from Bel toward Lake Pung	unknown	4	4
16	Manus	1996	Blume	0.5-meter-tall glowing figure	unknown	7	
17	Perth, Austr	1997	couple	giant, leathery-skinned, long tail	200 meters		
18	Umboi	unkwn	old man	end of tail was glowing as it flew	unknown	4	
19	Umboi	2001	Dianne A	light flew from Tarawe toward Bel	unknown	4	5
20	Umboi	2001	Jonah Jim	long tail glowing blue as it flew	200 meters	4	1
21	Umboi	2002	Kau+Anton	flew from Mt Bel toward the beach	unknown	4	4
22	Umboi	2002	Batsima	glowing ropen landed on a tree	unknown	4	~5
23	Umboi	2002	Mark Kau	ropen light flew from beach to Mt Bel	unknown	4	~6
24	Umboi	2002	Mark Kau	as ropen flew, tail was glowing red	unknown	4	
25	Umboi	2002	Mark Kau	ropen light flew from Mt Bel to beach	unknown	4	~6
26	Umboi	unkwn	Jos. Buko	white light flew toward the beach	unknown	4	~6

lights, and a physicist, Cliff Paiva, analyzed his footage, confirming that the images were not from a car, campfire, meteor, or photographic hoax (Paiva and Slusher, 2007). Two of Nation's native assistants, Pastor Jacob Kepas and Joseph, sighted a large winged creature in the area during the day; it appeared to be sleeping.

Early in 2007, the first noncreationist ropen expedition team—the television production, *Destination Truth*, led by

Josh Gates—videotaped a light similar to that videotaped by Nation. Two forensic experts could not explain the evidence.

Interview Methods

A language barrier forced us to often rely on interpreters and on the limited English skills of many eyewitnesses, although my limited skill in *Tok Pisin* was of some use. But some eyewitnesses from Umboi Island were more proficient

in English, and the cultural gap was less than it would have been if we had gone to an island other than Umboi, where there are several small schools.

Guessman and Woetzel prepared and administered formal interview procedures with a two-page questionnaire and a sketch page of 34 silhouettes of bats, birds, and pterosaurs, although the formal process was not used for all eyewitnesses. My interviews were less formal, relying on opportunities that

Table II. Sighting Descriptions (continued).

Ref.	Location	Year	Eyewitness	Description	Distance	Map-1	Map-2
27	Umboi	2003	Kau+Anton	it flew from beach toward Bel	unknown	4	~6
28	Umboi	2003	Abram	it flew from beach glowing red+white	unknown	4	5
29	Umboi	2003	Abram	light flew down to reef, as if fishing	1.5 km	4	A
30	Umboi	2003	Venice C	light over Gomlongon flew to beach	unknown	4	6
31	Umboi	2003	R Ambois	light over Arot Village scared them	unknown	4	~3
32	Umboi	2003	Zacharia	Owanga villagers saw it flying south	unknown	4	~5
33	Umboi	2004	Moke	light above reef (overhead)	unknown	4	A
34	Umboi	2004	Ragu	creature glowing as it flew	unknown	4	B
35	Umboi	2004	Pat. Sual	flies regularly: mountain to mountain	distant	4	~3
36	Umboi	2004	Gima	light above reef	unknown	4	C
37	Umboi	2004	Leonard	it flies over Opai Village once/month	unknown	4	~6
38	Umboi	2004	John Anton	light flies from Mt Bel toward beach	unknown	4	~6
39	Umboi	2004	Kenda-Kau	Large, glowing flying object	9 km	4	4
40	Umboi	2004	R Ambois	flew from Mt Bel to Mt Sual	unknown	4	4,3
41	Umboi	2004	R Ambois	flew from Mt Sual to Mt Tolo	unknown	4	3,1
42	Umboi	2004	D Nolo	skinny creature, glowing as it flew	unknown	4	~1
43	Umboi	2004	Woetzel	Large, glowing flying object	3 km	4	1
44	Tawa area	2006	Nation	several flying "indava" lights	distant	1	
45	Tawa Village	2006	Nation	two lights on a ridge (videotaped)	1.2 km	1	
46	Tawa area	2006	Kepas	winged creature sleeping on a cliff	unknown	1	
47	Tawa area	2006	Joseph	winged creature sleeping on a cliff	unknown	1	
48	Salamaua	2007	Gates	Large, glowing flying object	unknown	2	
49	Tawa area	2007	Nation	Large, glowing flying objects	unknown	1	

Table III. Expeditions.

Expedition	Key Participants	Location	Principal Results
1994	Baugh, Blume, Nation	Umboi Island	interviewed eyewitnesses
1996	Baugh, Blume	Manus Island	saw glowing forms
2001	M. S. (anonymous)	Bitoi Village	interviewed eyewitnesses
2002	Nation & son	Umboi Island	interviewed eyewitnesses
2004-W-K	Whitcomb, Kenda	Umboi Island	interviews; saw glowing form
2004-W-G	Woetzel, Guessman, Kepas	Umboi Island	interviews; saw glowing form
2006	Nation, Kepas, Joseph	Tawa Village	interviews; videotaped glowing forms
2007-JG	Josh Gates and associates	Salamaua	interviews; videotaped glowing form
2007-Nation	Nation	Tawa Village	saw glowing forms



Figure 3. Hodgkinson's choices of head sketches resulted in the composite on the left; Hennessy's, on the right. Choices were made on test sketches to determine characteristics such as beak sharpness and appendage length. The difference in appendage length ratio seems within the range of eyewitness error for these two sightings.



Figure 4. This wing-shape is from the Perth sighting; other details (length-to-wingspan ratio and head) are composited from details by Hennessy, Hodgkinson, and a few Umboi Island villagers.



Figure 5. The south side of Mount Tolo near Lake Pung and near where the flying light disappeared from Woetzel's view in 2004.



Figure 6. Typical Rhamphorhynchoid tail-vertebrae structure. This appears to be consistent with a tradition (north Umboi Island) about the ropen's tail movement. The interlocking structures prevent much movement except near the base, where the tail connects to the body.

arose with each eyewitness. For future work, I recommend beginning with this open-format questioning to take advantage of unique opportunities with eyewitnesses (the interviewer using a foreign language) and then following up promising leads with a questionnaire and sketch page (using interpreters).

Western Eyewitnesses

Several English-speaking Western eyewitnesses report sightings of possible pterosaurs. Freed from language and cultural barriers, communication is optimized in these situations, and greater detail can be gleaned from these witnesses.

Duane Hodgkinson

In 2004 I interviewed Duane Hodgkinson, of Montana, by e-mail, survey form, and telephone. He was then videotaped by Guessman in 2005. He and an army friend were in a jungle clearing west of Finschhafen (then New Guinea) in 1944 (Figure 1) when something "huge" took off into the air from the far side of the clearing. The creature ran to their left, taking six to ten steps to get airborne and ascended at an angle of about 30 degrees (similar to an airplane taking off). It then disappeared over the dense brush but soon returned and flew over the clearing, presenting a "perfect side view" of its features before again flying out of view. The wings never stopped flapping, at one to two seconds per flap, while it flew.

Hodgkinson recounted several morphological details. The girth of the body

at the chest was about 2 ft (0.6 m). He estimated the legs to be 3–4 ft (1–1.2 m) long. The top of the back was 5–6 ft (1.5–1.8 m) above the ground just before takeoff. Although he did not notice details of the tail, he estimated it was "at least" 10–15 ft (3–4.6 m) long. He compared the wingspan to a Piper Tri-Pacer airplane (~29 ft or 9 m). The length of the head, not counting the appendage, was about 3–4 ft (1–1.2 m), similar to the length of the neck. An appendage protruding from the head, above the neck, was about half that length, and both the head and appendage were parallel to the neck (Figure 3). During flight, the feet were tucked up to the body. Hodgkinson was unsure of other features. The color was dark but not black. He took no notice of any feathers or hair, and he remembered nothing about the eyes.

This sighting occurred at noon in a clearing with grass less than three feet in height. The weather was good, and there was no obstruction to Hodgkinson's view during the takeoff and during the return flight over the clearing. When the creature took off into the air, it was about "100 feet" (30 m) away from the men. When it returned to the clearing, it was flying about "50–100 feet" (15–30 m) high.

Brian Hennessy

In 2006, I interviewed Mr. Hennessy (a professional psychologist) by e-mail. On Bougainville Island, PNG, in 1971, he saw what he described as a "prehistoric" creature flying possibly about "50 m" (164 ft) above him. It was black or dark brown, with a "longish narrow tail"

and “no feathers in sight.” Its wingspan was “at least 2 m [6.6 ft], probably more...possibly much much more.... The head had no ‘normal’ beak. Rather there seemed to be (and this is difficult to describe) a kind of beak that was indistinguishable from the head, and the head seemed to continue this ‘point’ at the back of the head. There was a clear line running from the ‘beak’ to the back of the head where the ‘line’ continued to protrude.”

When asked if there “was anything coming out the back of the head—whether classified as a crest, appendage, horn, or comb,” he replied, “It was like a horn.” I asked about wing-flapping frequency, “how many seconds...for one cycle...up-and-down-flap,” and he replied, “Estimate every 2 seconds.” When asked about the tail, he answered, “As far as I can recall, straight.” I gave Hennessy a set of sketches, and his choices were remarkably similar to the results of my survey examination of Duane Hodgkinson (Figure 3).

Australian Couple

At about the time I was interviewing Hodgkinson in 2004, I found an old Internet forum posting in which an Australian lady was trying to persuade participants in a cryptozoology forum that she had seen a giant, living creature that looked like a pterosaur. I established e-mail communication with her and learned about her sighting in Perth, Australia in December of 1997. Her husband soon joined in my e-mail interview, but they prefer to remain anonymous.

The couple was walking together between two suburbs at about 10:00 p.m. when they first noticed the flying creature. As its gliding brought it closer, the couple was shocked, for it had a “lizard appearance” and a reported “size” between 30 and 50 ft (9–15 m). The lady declared, “It was definitely a living creature.... We would not have been able to see what it was if the ground lighting had not lit its underside.”

The lady admitted to me that her husband probably could give a better accounting of the sighting, for she was too shocked to take in details and her husband works in a scientific field and seems to have observed and remembered more. He reported, “Within a minute or so it had reached our position and was about 250 or 300 ft [76 to 91 m] above us and slightly inland. The area was [moderately] well lit...it seemed to be a light [reddish-tan] color. It did not appear to be covered with feathers but had a leathery texture.”

He continued, “Soon after it passed us, it flew over a more brightly lit sports area which highlighted even more the leathery appearance, also bringing more detail to view. The wings were the most [definite] leathery feature; they were shaped in an [triangular] arch, similar to a very [elongated] shark fin [Figure 4]. The body also still appeared leathery, though textured as though possibly covered with fine hair or small scales, the distance preventing any finer observation other than that it was [a] slightly different texture than the wings. The shape of the body was a streamlined torpedo shape, slightly broadest at the chest and tapering slightly back to the hip, then tapering more quickly after the hips to a moderately thin tail, which was slightly longer than the body. At the hips the legs appeared to be tucked in close to the body.... The head was close to the body, though whether from a short neck or from having its head drawn in in the manner of some long-necked waterfowl I cannot say.... The creature...was mostly gliding...some wing movement as in a hawk or other bird controlling its flight path, but did not flap as a sparrow or other small bird.... the wing span was greater than the length of the body proper, or a bit more than half the total length, the tail being slightly longer than the body. Size is of course hard to determine accurately at a distance, since even a small miscalculation in distance can magnify any error in the estimate. I, at

the time however estimated the size to be in excess of 30 ft, possibly as great as 50 ft [referring to wingspan]. My eyes told me it was nearer the greater of these; my rational mind wants me to believe the lesser, since either of these is astounding for a flying creature.”

Their answers to the survey form I had sent the couple showed some similarity to the Hodgkinson and Hennessy creatures, but there were differences in the wing shape, wingspan-to-total-length ratio, coloring, and possibly the relative neck length.

David Woetzel

Although Woetzel saw neither shape nor features during his ropen-light sighting on Umboi Island in 2004, his report is significant, for he was looking for the ropen and was prepared to take note of anything he saw. His description was distinctly unlike meteors or man-made lights. Significantly, the object disappeared behind the crater-mountain system of Lake Pung (Whitcomb, 2006), where other sightings have taken place, suggesting the ropen’s destination was that lake (Figure 5).

Paul Nation

The first American to bring back video evidence for the bioluminescence of the ropen was Paul Nation, who explored near Tawa Village in late 2006. He saw a number of flying lights on several nights and videotaped, for about fifteen seconds, two lights that were on a ridge where there were no roads, cars, or campfires. His early-2007 expedition was less productive but still resulted in sightings of the flying lights. Local villagers call the creature “indava.”

Native Eyewitnesses

Jacob Kepas

Few eyewitnesses have clearly sighted a ropen more than once. Jacob Kepas is an exception, with two sightings. He

is also the first nonlocal explorer to have seen a pterosaur-like form while assisting an organized ropen search. As a Baptist minister born in PNG but trained by missionary Jim Blume, he understands both native traditions and Western ideas about the creatures. He became actively involved in the investigations after assisting, as an interpreter, the Woetzel-Guessman Umboi Island expedition of 2004.

His first sighting was at night, when he was about twelve years old (Whitcomb, 2006) (Table II). Hearing the noise of the flying creature (known in his village as “seklo-bali”), he looked up and briefly saw the wings and tail; significantly, he also saw a glow from the creature. His second sighting came in daylight, in the Tawa Village area, late in 2006. It was at a distance that required binoculars, and Kepas reported that he saw what might have been the head of a giant indava partially covered by a wing; the creature appeared to be sleeping. The viewing angle was poor, but a local man named Joseph climbed to a higher vantage point and declared that it was the creature they sought. Unfortunately, their video recording failed to show what the two men saw through the binoculars, and Paul Nation was not present at that event.

Gideon Koro, Wesley Koro, and Mesa Agustín

In about 1994, at Lake Pung, Umboi, and in daylight, seven boys, aged about eleven to sixteen, saw what three of them (in 2004) told me was a ropen (Table II). Their testimonies were videotaped during an interview in the Awelkon Village area (Figures 7 and 8).

According to Gideon Koro, who speaks some English, a few minutes after they had arrived at the lake, “it came down.” I tried to ask about wingspan but at that point had to rely on an interpreter (using the Kovai language), and only later did I realize that he probably thought that I meant the length of *one* wing. In

either case, his answer is astonishing: “seven meetuh” (seven meters). When I asked about the tail length, he pondered, seeming to recall and estimate; then he said, “seven meetuh.”

Gideon was sure that the creature was a ropen. He hesitated before giving the color (probably searching for the English word): “brown.” When I asked about feathers, he at first appeared to be puzzled; his answer and mannerisms then seemed to me to reveal that he was surprised that I should ask that question: “There’s no feathers” (Figure 7). I then asked, “Was there just skin?” The Kovai word “byung” came up as did the English term “flying fox.” Gideon agreed that the skin was like that of a fruit bat.

When I asked about the back of the head (hoping for information on a head crest), another villager interpreted: Gideon had not seen the head clearly enough to answer that question. I asked about the mouth, and Gideon thought for a while before answering, “Its mouth like a crocodile.”

Soon thereafter I made three drawings in the dirt. I drew two similar versions of the creature’s head; one with crocodilian-like eye sockets and the other without the eyes at the top of the

head. Gideon immediately chose the non-crocodilian head. I also started a drawing of a large head (with a long snout), which Gideon completed by drawing the body, wings, and tail (Whitcomb, 2007). His drawing suggested a tail length of about half the wingspan, or about the length of one wing.

The other two men interviewed were Wesley Koro and Mesa Agustín (Figure 8). They confirmed that they had been with Gideon and had also seen the ropen at Lake Pung. Both of these eyewitnesses mentioned a “diamond” on the tail, which may have been a structure similar to the tail flange of fossil Rhamphorhynchoids, but I failed to use the drawing-in-the-dirt method to confirm its morphology.

Jonah Jim

Within minutes of completing the interviews with Gideon, Wesley, and Mesa, while on the road back to Gomlongon Village, our expedition team met a local villager named Jonah Jim. I spent little time interviewing him, since I had to catch the next boat to the mainland. He sighted a ropen in 2001, near our interview site (Figure 5). He saw both a long tail and a glow from the ropen.



Figure 7. Throughout Gideon’s videotaped 2004 interview, his facial expressions consistently communicated in harmony with his words. Here, he expresses puzzlement when asked about feathers. He then said, in English, “There’s no feathers.”



Figure 8. Like the other two Pung-sighting eyewitnesses interviewed in 2004, Mesa ran away after seeing the ropen in 1994. But, unlike the other two, he still acted fearful or anxious during the interview ten years later.

Only later did I realize the importance of his testimony: He had confirmed that the flying glow is a large, long-tailed flying creature.

Fortunately, a few weeks later Guessman and Woetzel interviewed Jonah Jim (Table I). Jonah Jim chose the *Sordes Pilosus* when given a choice between thirty-four silhouettes. He estimated the wingspan at 20–23 ft (6–7 m) and the tail at 8–10 ft (2.5–3 m). Unlike Gideon Koro, Jonah Jim clearly understood that “wingspan” referred to both wings. He also noted that only the tail was glowing.

Jonathan Ragu

In 2004, Jonathan Ragu and his daughter saw a ropen, with a nose-to-tail length of about 11 ft, flying away from Umboi Island’s northwest coast, toward Tolokiwa Island. It glowed brightly from the head and trailing edges of the wings. From the thirty-four silhouettes of birds, bats, and pterosaurs, Jonathan chose the *Sordes Pilosus*.

Are the Creatures Rhamphorhynchoid Pterosaurs?

Although a modern, giant, long-tailed (Rhamphorhynchoid) pterosaur with a head crest seems impossible in an evolutionary framework, eyewitness accounts suggest that if this pterosaur is not extant, then there is a creature amazingly similar living in remote regions of the southwest Pacific area. If we set aside the old-earth evolutionary framework, several problems still remain. How could such a large unusual creature escape the notice of Western science for so long? Would the creature be a Rhamphorhynchoid or a Pterodactylid? After all, some short-tailed Pterodactylids were giants, and many had head crests. The reported bioluminescence is strange too.

The ropen may have remained unknown to Western science for several reasons. First, eyewitness testimony sug-

gests the creature is primarily nocturnal; about half of the rare daylight sightings involve startling a sleeping ropen. Second, the paucity of even native eyewitness accounts indicates that the creature is quite rare. Third, its apparent territory is largely unexplored wilderness and jungle. Finally, few Western scientists or explorers would think to look for a creature that they were convinced was long extinct. So it is certainly possible, even if it seems unlikely, that such creatures really exist. At present, we must rely on indirect evidence, such as eyewitness accounts. What do they actually tell us?

First, the creature is large, but not usually gigantic. Although a few sightings were made of very large creatures, our investigations do not indicate that a typical ropen is a giant. The largest ones are more easily noticed; smaller ones might be mistaken for birds. According to Jim Blume, in the Manus Island area (Figure 1) typical ropen wingspans are reported to be only 3–4 ft. Nevertheless, a few daylight sightings indicate that some can reach wingspans greater than 20 ft.

Second, the creature appears to possess a head crest similar to some pterosaurs (Figure 3). Recent fossil evidence suggests that, with at least one species of pterosaur, head crests grew as the creatures matured (Naish, 2006). Thus, the presence and/or size of a head crest may relate to maturity and thus to overall size; fossils of the small species *Sordes Pilosus* show no head crest. Although no discovered fossil of a *Sordes Pilosus* is large, a closely related species, *Scaphognathus* (Wellnhofer, 1991), possesses a Rhamphorhynchoid head crest (Goertzen, 1998).

Finally, most reports include testimony of some kind of associated glow, possibly bioluminescence. It has been seen by natives and Westerners and videotaped, and the video footage has been analyzed by both creationist and non-creationist experts, none of whom found any commonplace explanation.

The creationist’s analysis was deeper, and he specifically eliminated any possibility of meteors, camera artifacts, campfires, lanterns, paste-on photo-hoax, or car headlights.

Bioluminescence in flying creatures is not restricted to fireflies. Silcock (2003) reports bioluminescence in barn owls in Australia. But ropen lights do not behave like hunting barn owls. When over land, their altitude has been described by more than one eyewitness as “about 100 m” (328 ft), while owls often fly 3–10 ft high. Ropen lights are also faster, according to villagers of Tarawe, Umboi Island, “faster than birds; slower than airplanes.” They’re also brighter and sometimes fly down to reefs around Umboi Island. The purpose of the lights is unknown. They could be used as a close navigation aid over the jungle canopy (100 m is just above the canopy), and/or as a fishing aid on the reefs. David Moke of Opai told me that underwater flashlights can put fish to sleep (Whitcomb, 2007). Not all ropen lights behave the same; the indava lights last much longer than the 5–6-second flash of the ropen light of Umboi.

Non-Rhamphorhynchoid Possibility

Despite similarities between reported sightings and Rhamphorhynchoid fossils, the ropen could be a completely unknown creature. Of the eight American creationists who visited PNG (from 1994 through 2007) to search for the ropen, one returned unconvinced of its existence. We know that long-tailed pterosaurs lived in the past and that an unknown creature is reported in the southwest Pacific, witnessed by natives and a few Americans and Australians. Photographs and videos are needed to confirm eyewitness descriptions.

From the Guessman-Woetzel expedition, we learned that the tail of the ropen is stiff, never moving except where it connects to the body, according to one village of northern Umboi.

This corresponds to knowledge of fossil Rhamphorhynchoids (Wellnhofer, 1991). The tail vertebrae are built to prevent much movement, except where the tail connects to the body (Figure 6).

Dimorphodon or Sordes?

After his 2004 expedition, Woetzel concluded that the ropen is similar to a *Dimorphodon*, a Rhamphorhynchoid pterosaur (Woetzel, 2006a, p. 249), citing “strong legs and powerful bipedal locomotion” and a “short, heavy beak and face” and eyewitness matching of color pterosaur pictures of *Dimorphodon*.

There were many brief interviews that we conducted along the trail, oftentimes without the time to do a detailed questionnaire with our prepared sheets or the video camera rolling.... Stories...emphasized the human-like face... (Woetzel, 2006b, p. 132).

But it appears that they did not properly evaluate all the evidence (Whitcomb, 2006). At least some of their brief interviews were done without discriminating whether the original source was oral tradition or eyewitness testimony. Detailed interviews of a few eyewitnesses are more valuable than many brief ones. The best Guessman-Woetzel interviews were the formal surveys of eyewitnesses, but these do not appear to have led to Woetzel’s choice of a *Dimorphodon*-like ropen. It seems reasonable that the “stories told to us” may include elements of the superstition that the ropen can transform itself into a man. That belief may have unduly influenced descriptions of the ropen head. It is also possible that its sightings in trees gave it the appearance of a humanlike upright stance.

By the time they had reached Opai Village, Guessman and Woetzel had heard numerous accounts of the ropen’s appearance. The old man they videotaped in Opai chose the *Dimorphodon* sketch, but why? To what extent was the witness influenced by traditions?

Was the interview sufficiently detailed to elicit why the old man chose that silhouette? It appears that he was not given the complete survey interview but only a brief questioning.

It is interesting that of the two Woetzel-Guessman eyewitnesses with sightings clear enough to recall wing-shapes both chose the *Sordes Pilosus* from among the thirty-four silhouettes. Also, the detailed accounts from Hodgkinson and Hennessy included a long tail and a long thin beak (*Sordes*-like) (Figure 3). Their sightings were 60 miles (97 km) south and 500 miles (805 km) east of Umboi, respectively. Although Gideon had a limited view of the head of the ropen he saw on Umboi, his choice of a crocodile mouth (but with no teeth observed) suggests a *Sordes* more than a *Dimorphodon*. Thus the bulk of the most credible evidence suggests a *Sordes*-like ropen.

But the many traditions supporting a “short, heavy beak and face” deserve attention. Jim Blume’s long-term research, interviewing dozens of native eyewitnesses, includes some descriptions suggesting a creature with a beak more like a *Dimorphodon* than a *Sordes*, and some hearsay reports from Indonesia support the idea of a shorter beak or face (the creature there is called “*ahool*”). Also, wooden carvings produced on the PNG mainland show a short beak, though the artists were not eyewitnesses (Woetzel, 2006a, p. 248).

Critics

Eyewitness Reliability

As of mid-2007, the case for living pterosaurs in the southwest Pacific relied mostly on eyewitnesses. Since analysis of the videos of the flying lights did not reveal any creature, there is still no direct evidence. Critics have suggested several reasons for doubting the accounts, but I suggest that most of these do not hold up under analysis; they include:

- Sightings were of the fruit bat called the “flying fox” (Kuban, 2007). But that bat has a maximum wingspan of 6 ft, and the best sightings that we have investigated include wingspan estimates that range from “at least 2 m, probably more” (Hennessy) to “30 and 50 ft” (Perth couple). The bat has almost no tail, unlike the reported tail of “at least 10–15 ft” (Hodgkinson) or “7 m” (G. Koro). It has no head crest, nor does it glow at night. Two hunters on Umboi Island witnessed a ropen hanging upright on a tree trunk; the bats hang head-down from branches (Table I). These details, as a whole, preclude bat sightings.
- Sightings were hallucinations (Portail francophone de cryptozoologie, 2007). This seems unlikely, given multiple sightings by different people from different cultures at different times. Hallucinations produce images related to personal knowledge, so why would educated Westerners and native islanders hallucinate the same object?
- Sightings result from native superstition. One news account tried to connect native sightings of a “dinosaur” with superstition (*Sidney Morning Herald*, 2004). But the native eyewitnesses of the ropen did not refer to superstitions, nor would Western witnesses share these beliefs.
- Testimony comes from coaching witnesses (Cryptid Analysis). But no evidence is provided to back up this assertion. The witnesses are available for “cross-examination” but critics have not appeared interested.
- Sightings were contrived (Cryptid Analysis). This falls into the category of a conspiracy theory, since many people have report-

ed seeing the same thing. But why would many diverse people be dishonest about the ropen? They have no motive. And Western witnesses have maintained their accounts for many years, at the risk of their reputations and possibly their careers; they have nothing improper to gain by reporting their sightings. Dishonesty is always possible but is very unlikely in this case, given the people, circumstances, and careful interviews. At least some of the accusations of dishonesty come from critics who believe that creationists in general are dishonest (cryptozoology.com, 2005), but this comes from their own bias, which precludes the possibility of extant pterosaurs.

Investigator Reliability

A few critics have suggested that living-pterosaur investigators are dishonest (Dinosaurs and The Bible, 2007) but to date have offered no evidence. From 1994 through early 2007, eight American creationists have traveled to PNG in eight expeditions (one to three Americans per expedition). These expeditions involved personal financial sacrifice. During those thirteen years, no American investigator has claimed a personal sighting of anything resembling a pterosaur. If we were dishonest, it seems that at least one false report would have been made. Surely someone would have reported something other than distant flashes of light. Furthermore, the numerous videotaped interviews of eyewitnesses force these critics to either drop the subject or to insinuate that everyone is lying.

It is worth noting that an apparent identity hoax occurred in mid-2007. A YouTube Internet video purportedly submitted by a "David Woetzel" showed a flying, long-tailed creature. The associated caption included the word "ropen." There was evidence that the image had been contrived (another kind of hoax).

But David Woetzel had no association with the video, and following an investigation, it was removed by the YouTube supervisor and the account holder's account was terminated. No investigator or eyewitness was associated with that video, but the event damaged the reputation of living-pterosaur investigators among cryptozoologists. Still, most criticisms relate to the fact that we are creationists.

Implications for Evolution

Critics have stated that the discovery of a living pterosaur, although of great scientific significance, would prove nothing in the creation/evolution debate. But their assertion suggests a dogmatic adherence to the philosophy of evolution. Any empirical evidence can be explained away—it often has been—and those who have committed their allegiance to evolution can choose to be unconvinced, regardless of evidence. Nevertheless, many who now accept it because they have been taught that it is "science" can be strongly affected by negative empirical evidence.

The discovery of a living creature very similar to an "ancient" pterosaur would be such evidence, similar to the discovery of other "living fossils," such as the Coelacanth. But, unlike the discovery of the formerly-obscure Coelacanth, the discovery of a living Rhamphorhynchoid pterosaur could awaken a new examination of standard-model assertions: not only the universal extinctions of dinosaurs and pterosaurs but universal common ancestry itself. Evolution-based theories about dinosaurs and pterosaurs have been promoted for generations, especially the idea that they are ancient creatures. "Prehistoric" animals are seen on television, movies, children's books, and food packages. Children fall asleep to stories of "extinct" creatures, but a living pterosaur could cause a philosophical reawakening: a reexamination of old assumptions.

Summary

At least one species of rare nocturnal flying creature—the ropen—lives in the southwest Pacific. Fossils of long-tailed pterosaurs show features similar to those related by some eyewitnesses, especially of the ropen's tail: a "diamond" that may be a tail-end flange and the reported motion of those tails, also similar to Rhamphorhynchoid tails. The largest ropens, probably extremely rare, may attain sizes up to 50 ft in wingspan. Those size descriptions alone, from credible eyewitnesses of three nationalities, make it unlikely that the sightings were misidentifications of birds or bats. Many eyewitness reports and some video evidence suggest a brightly bioluminescent flying creature. Circumstantial evidence supports that idea (the ropen-lights are sighted in some of the same areas where eyewitnesses have seen, in daylight, large unclassified winged creatures).

Opposition to cryptozoological investigations related to apparent dinosaurs or pterosaurs can come from the conflict between evolutionary naturalism and literal interpretations of Genesis-Creation. Opponents have suggested numerous explanations for the numerous sightings, but none are credible. In fact, more recent investigations have justified earlier eyewitness accounts. In late 2006, ropen lights were videotaped, and two ropen searchers saw a very large creature asleep during the day (Tawa Village). In early 2007, another ropen light was videotaped.

Until one is captured (or at least until significant photographic or video evidence is obtained), the possibility of living pterosaurs remains in the realm of cryptozoology. Nevertheless, existing evidence is sufficient to justify ongoing investigations into the creature we call "ropen."

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Why the Inverted Human Retina Is a Superior Design

Jerry Bergman* and Joseph Calkins**

Abstract

It is often claimed that the human retina is poorly designed because light must travel through the nerves and blood vessels to reach the photoreceptor cells, which are located behind the eye's wiring. Many specific reasons exist for this so-called backward placement of the photoreceptors. A major one is that it allows close association between the rods and cones and the pigment epithelium required to maintain the photoreceptors. It is also essential in both the development and the normal function of the retina. Both the rods and cones must physically interact with retinal pigment epithelial cells, which provide nutrients to the retina, recycle photopigments, and provide an opaque layer to absorb excess light.

Introduction

One of the most common examples of putative poor design in both the popular and scientific literature is the mammalian retina. The retina is the thin, light-sensitive organ located at the back of the eyeball. The claim is made that the vertebrate eye is functionally suboptimal because the retina photoreceptors are oriented *away* from incoming light (Ayoub, 1996, p. 19). Oxford professor Richard Dawkins considers this an example of poor design because he concludes that an

engineer would naturally assume that the photoreceptors would point

towards the light, with their wires leading backwards towards the brain. He would laugh at any suggestion that the photoreceptors might point away from the light, with their wires departing on the side *nearest* the light. Yet this is exactly what happens in all vertebrate retinas. Each photoreceptor is, in effect, wired in backwards, with its wire sticking out on the side nearest the light. The wire has to travel over the surface of the retina, to a point where it dives through a hole in the retina (the so-called 'blind spot') to join the optic nerve. This means that the light, instead of being granted

an unrestricted passage to the photoreceptors, has to pass through a forest of connecting wires, presumably suffering at least some attenuation and distortion (actually probably not much but, still, it is the principle of the thing that would offend any tidy-minded engineer!) (Dawkins, 1986, p. 93).

Tufts University Professor Daniel Dennett argued that, although the eye design is brilliant,

it betrays its origin with a tell-tale flaw: the retina is inside out. The nerve fibers that carry the signals from the eye's rods and cones (which sense light and color) lie on top of them, and have to plunge through a large hole in the retina to get to the brain, creating the blind spot. No intelligent designer would put such a clumsy arrangement in a camcorder, and this is just one of hundreds of accidents frozen in evolutionary history that confirm the mindlessness

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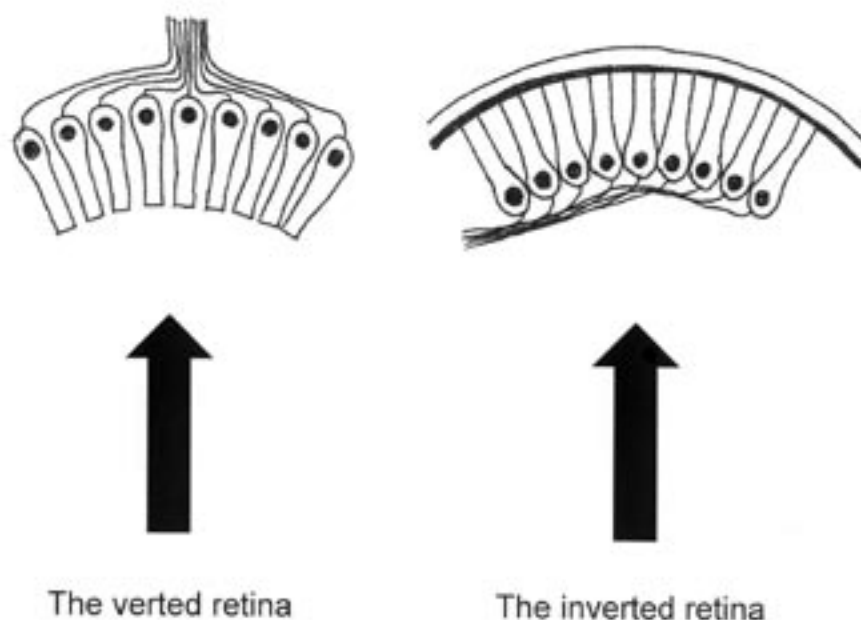


Figure 1. The basic design of the verted (left) and inverted (right) retinas, showing the light-sensitive cells. The arrow shows the direction the light travels into the retina. Note in the verted retina (left) the light-sensitive cells face toward the light, and in the inverted retina (right) design used in humans the light-sensitive cells face away from the light source. Drawing by B. L. Lindley-Anderson after Land and Nilsson (2005).

of the historical process (Dennett, 2005, p. 4).

Williams claimed the retina is not just an example but one of the *best* examples of “poor design” in vertebrates that proves a “blind watchmaker” created life.

Every organism shows features that are functionally arbitrary or even maladaptive.... My *chosen classic* is the *vertebrate eye*. It was used by Paley as a particularly forceful part of his theological argument from design. As he claimed, the eye is surely a superbly fashioned optical instrument. It is also something else, a superb example of maladaptive historical legacy.... Unfortunately for Paley’s argument, the retina is upside down. The rods and cones are the bottom layer, and light reaches them only after passing through the

nerves and blood vessels (Williams, 1992, p. 72, *italics added*).

Williams (1992) admitted that the vertebrate eye still functions extremely well in spite of the backward retina and argued that this does not negate the “fact of maladaptive design, however minimal in effect,” which disproves “Paley’s argument that the eye shows intelligent prior planning” (p. 73). Barash and Barash (2000) even claimed that the human

eye, for all its effectiveness, has a major design flaw. The optic nerve, after accumulating information from our rods and cones, does not travel directly inward from the retina toward the brain as any minimally competent engineer would demand. Rather, for a variety of reasons related to the accidents of evolutionary history plus the vagaries of embryonic development, optic-nerve fibers first

head away from the brain, into the eye cavity, before coalescing and finally turning 180 degrees, exiting at last through a hole in the retina and going to the brain’s optic regions (p. 296).

After noting that the backward retina is a “classic” example of the “stupid features which support the idea that they are the result of evolution by natural selection” Frymire (2000) concluded that the inverted retina “results in an absurd situation in which the light has to travel through blood vessels and nerves before it reaches the rods and cones” (p. 36). Diamond (1985) added that, of all of our features,

none is more often cited by creationists in their attempts to refute natural selection than the human eye. In their opinion, so complex and perfect an organ could only have been created by design. Yet while it’s true that our eyes serve us well, we would see even better if they weren’t flawed by some bad design. Like other cells in our bodies, the retina’s photoreceptor cells are linked to a network of blood vessels and nerves. However, the vessels and nerves aren’t located behind the photoreceptors, where any sensible engineer would have placed them, but out in front of them, where they screen some of the incoming light.... By contrast, the eyes of the lowly squid, with the nerves artfully hidden behind the photoreceptors, are an example of design perfection. If the Creator had indeed lavished his best design on the creature he shaped in his own image, creationists would surely have to conclude that God is really a squid (p. 91).

Kenneth Miller claimed that a prime example of “poor design” is the fact that in the human eye light has to travel through the neuron layers before it reaches the retina photoreceptors. He argued that this design provides clear evidence that the eye evolved by muta-

tions and natural selection and was not designed. An intelligent designer, he maintained, would not have placed “the neural wiring of the retina on the side facing incoming light. This arrangement scatters the light, making our vision less detailed than it might be” (Miller, 1999, p. 10). Thwaites (1982) argued that the inverted retina problem hits at the *core* of the design argument, historically a major basis of theism, because the “vertebrate eye shows poor design when compared to the eye evolved by the cephalopods” because vertebrates see everything

through the nerves and blood vessels of the retina since the photosensitive elements of the retina are on the far side of the retina away from the light source. Clearly the cephalopod solution to retinal structure is more logical, for they have the photosensitive elements of the retina facing the light. Certainly the creationists need to explain why we got the inferior design. I had thought that people were supposed to be the Creator’s chosen organism (p. 210).

Shermer claimed that anatomy of the human eye shows it is not intelligently designed because it is

built upside down and backward, with photons of light having to travel through the cornea, lens, aqueous fluid, blood vessels, ganglion cells, amacrine cells, horizontal cells, and bipolar cells, before reaching the light-sensitive rods and cones that will transduce the light signal into neural impulses (Shermer, 2005, p. 186).

Williams (1997) added that “our eyes, and those of all other vertebrates, have the functionally stupid upside-down orientation of the retina” and that the “functionally sensible arrangement is in fact what is found in the eye of a squid and other mollusks” (pp. 9-10).

The so-called inversion of the retina is considered a suboptimal design primarily because of its simplistic compari-

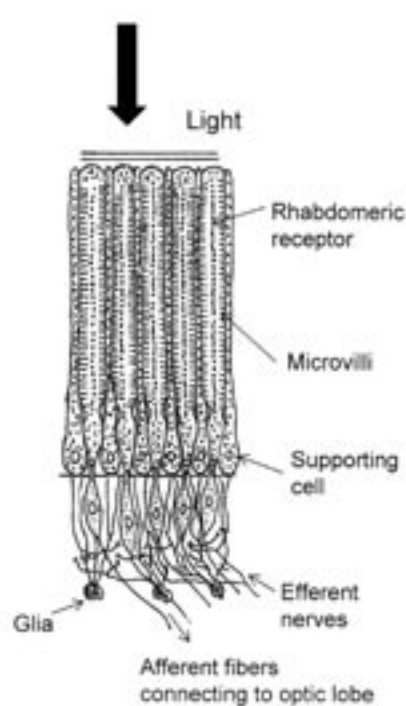


Figure 2. A cross section of the cephalopod eye receptors, called rhabdomeric receptors, which contain light-sensitive cells directly exposed to the incoming light. Note that the function of the pigment retina epithelium is served by the supporting cells located between the light-sensitive cells, reducing their number. Drawing by B. L. Lindley-Anderson after Land and Nilsson (2005).

son with a camera. Diamond argued that placing the rods and cones at the bottom layer and requiring light to pass through the nerves and blood vessels is the opposite of how an engineer would have designed the eye, and “a camera designer who committed such a blunder would be fired immediately” (Diamond, 1985, p. 91). And Edinger (1997) concluded that the “vertebrate eye is like a camera with the film loaded backward...if an engineer at Nikon designed a camera like that, he would be fired” (p. 761). This conclusion is based not only on

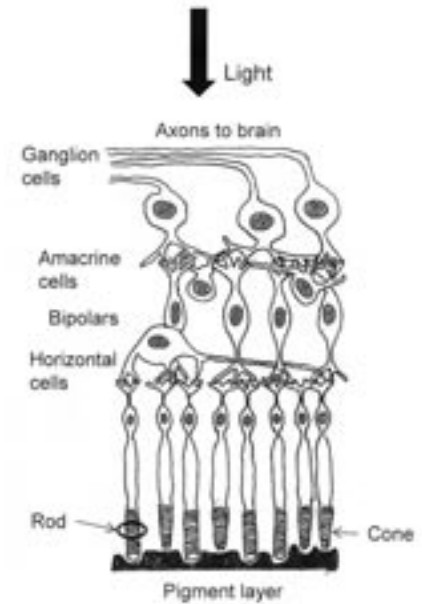


Figure 3. A cross section of the vertebrate retina, showing the retina pigment epithelium and other retina structures. Note the ganglion cells, the amacrine cells, the bipolar cells, and the horizontal cells. These are some of the structures that light must pass through before striking the photoreceptors, the rods and cones. The retina pigment epithelium absorbs the light and supplies the photoreceptors with nutrients among other functions. Drawing by B. L. Lindley-Anderson after Land and Nilsson (2005).

the assumption that placing nerves and blood vessels in *front* of the retina reduces the retina’s overall effectiveness, but also that another design would, as a whole, be superior. An evaluation of this argument reveals it is not only naive but also grossly erroneous.

Verted and Inverted Eyes

Research has clearly shown why the human retina must have an “inverted” design, forcing the incoming light to travel through the front of the retina to

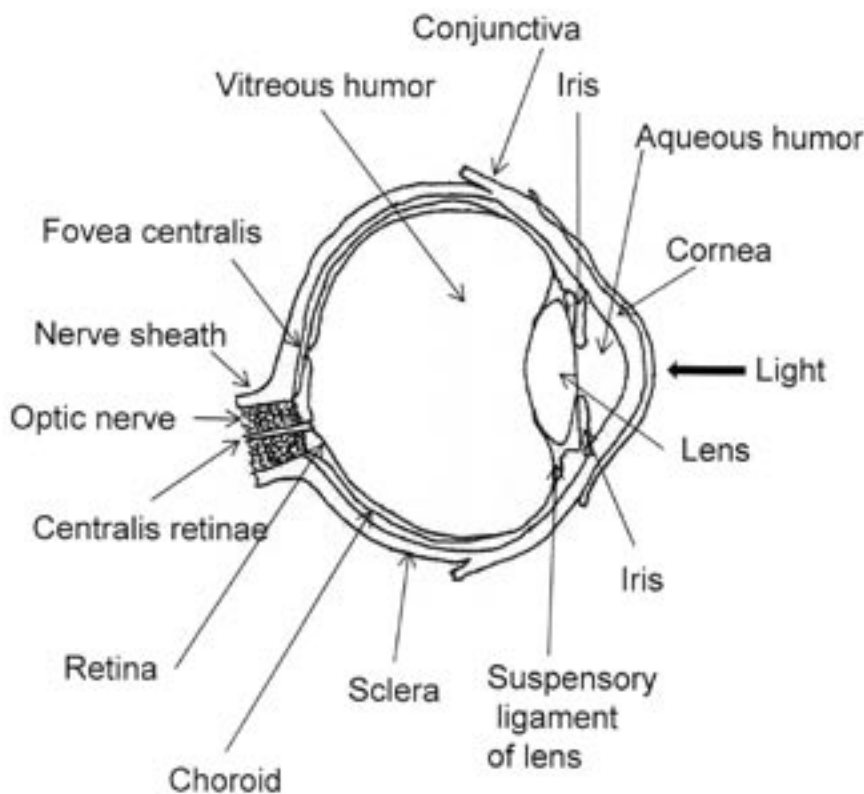


Figure 4. A cross section of the vertebrate eye illustrating some of its major structures. Drawing by B. L. Lindley-Anderson after Land and Nilsson (2005).

reach the photoreceptors. The opposite placement (where the photoreceptors face the front of the eye) is a “verted” design. Verted eyes are wired so that the photoreceptors face toward the light and the nerves are placed behind the photoreceptor layer (Miller, 1994, p. 30).

Most invertebrates and the pineal or dorsal eyes of lower vertebrates use the verted eye design, and most vertebrates (including mammals, birds, amphibians, and fish) use the inverted design. Most verted eye designs are very simple, although a few, such as the cephalopod eye (squids and octopi), are almost as complex as the vertebrate eye (Abbott et al., 1995). Even the better verted eyes are still “overall quite inferior to the vertebrate eye,” a conclusion usually

determined by measuring performance in response to visual stimuli (Hamilton, 1985, p. 60).

The Cephalopod Visual System

There are several reasons to conclude that evolutionists incorrectly understand the design of the inverted eye. The most advanced invertebrate eye known today is that used by certain cephalopods, but the most advanced eye may actually be the extinct trilobite (Bergman, 2007). The cephalopod visual system is poorly understood, both because it is so complex and because understanding its design is not a funding priority—as is research related to cancer or heart disease. It is known that the major ana-

tomical difference between the human eye and the advanced cephalopod eye, such as the octopus, is the retina. The cephalopod retina is not only verted but also lacks the most sensitive part of the retina, the *fovea centralis* (Land and Nilsson, 2005, p. 64).

In contrast to the claims of Dawkins and others, no evidence exists that even the most advanced verted cephalopod eye is superior to the inverted eye. The sensitivity of the existing human inverted design is so great that a single photon is able to elicit an electrical response (Baylor et al., 1979). Consequently, functional sensitivity of the verted retina could not be significantly improved:

Neurobiologists have yet to determine how such a negative system of operation might be adaptive, but they marvel over the acute sensitivity possible in rod cells. Apparently rod cells are excellent amplifiers. A single photon (unit of light) can produce a detectable electrical signal in the retina, and the human brain can actually “see” a cluster of five photons—a small point of light, indeed (Ferl and Wallace, 1996, p. 611).

Greater sensitivity than this single photon threshold, if this were possible, might actually result in poorer vision due to sensory overload. In a similar fashion, Williams syndrome patients have superior hearing compared to those with average hearing, allowing them to hear a faint whisper; however, this sensitivity causes them serious sensory overload problems such as in dealing with loud noises like thunder, which is actually physically painful.

Physiologically, the verted cephalopod retina is simpler compared to the inverted vertebrate retina. An example is there are “no equivalents of the amacrine, bipolar or ganglion cells in the cephalopod retina” (Wells, 1978, p. 150). The optic lobes, located behind the eyeball in cephalopods, must assume many of the image processing functions that occur in the inverted retina in ver-

tebrates. As an underwater animal that usually lives on the ocean bottom, its eye is designed to detect motion, not detail, as is true of human eyes. It must also maximize its utilization of light, since the ocean usually has little or no light at lower depths. The cephalopod eye

undoubtedly forms an image, but the animal's visual perception is certainly quite different from that of man, which is greatly dependent upon interpretation by the brain. The cephalopod optic connections appear to be especially adapted for analyzing vertical and horizontal projections of objects in the visual field (Barnes, 1980, p. 454).

Pechenik (1991) indicated that although cephalopods can perceive shape, light intensity, and texture, they lack many of the advantages of an inverted retina, such as the ability to perceive small details. The cephalopod visual system is designed very differently from the inverted eye in other ways to enable them to function in their water world. Most cephalopods, including octopi, have only one visual pigment and are thus color-blind (Land and Nilsson, 2005).

Furthermore, the maximum resolvable spatial frequency in cycles per radian is 4,175 for humans and only 2,632 for octopi (Land and Nilsson, 2005). Their photoreceptor cell population is composed entirely of rods, which contain a "mere" 20 million retina receptor cells, compared to 126 million in humans (Young, 1971). Their rod outer segments contain rhodopsin pigment that has a maximum absorption in the blue-green part of the spectrum (475 nanometers [nm]), which is the predominant color in their environment. Photons change the rhodopsin to metarhodopsin, and no further breakdown or bleaching occurs (Wells, 1978). A second octopus retina pigment, retinochrome, has an absorption maximum of 490 nm, which is more sensitive to dim light (Wells, 1978). Humans have one

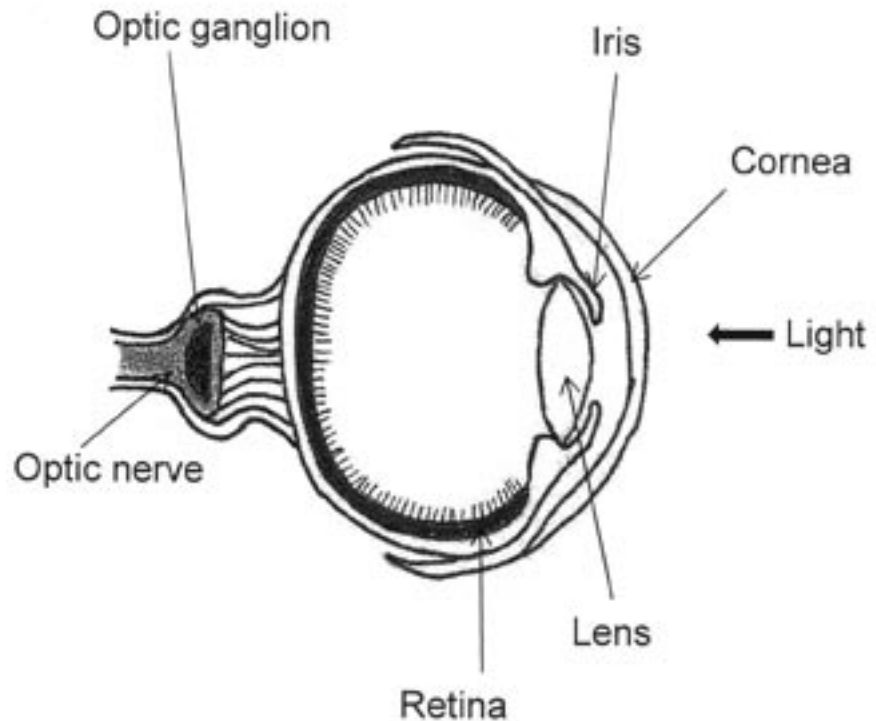


Figure 5. A cross section of the vertebrate cephalopod rhabdomeric eye, illustrating some of its major structures. Also, note the large optic lobe located posterior to the eyeball, a structure that does much of the light processing completed by the vertebrate retina. Drawing by B. L. Lindley-Anderson after Land and Nilsson (2005).

rod type and three cone types. One cone type has a broad peak light frequency of 440 nm (blue), another type 540 nm (green), and the third type 570 nm (red) (Stoltzmann, 2006).

The squid's visual system must function in an aqueous medium. Water acts as a filter, and, as a result, the light is of a much lower intensity. Consequently, a squid's vision sensitivity is for shorter wavelengths (below around 400 nm) than a human's, which is from 400 to 700 nm (Peet, 1999). In bright light the cephalopod's pupils become thin and slit-shaped and are held in a horizontal position by a statocyst, an organ that uses gravity to determine the horizontal (Young, 1971). Their visual process is "quite similar to that of the batrachians, reptiles and insects. A 'photograph' of

the recorded image is not traced on the retina as in man; instead cephalopods respond only to 'light and color variations of a moving object'" (Grzimek, 1972, p. 191).

Significantly, the octopus responds to certain motions of nonfood objects as if they were prey, but will not react to their normal food-objects if motionless (Spigel, 1965). The importance of motion supports the observation that the octopus eye is actually a simple "compound eye with a single lens" because each receptor cell is surrounded by photopigment containing microvilli, which form a rhabdomeric structure like a compound lens (Budelmann, 1994, p. 15). Each facet in a compound eye is either on or off, and object movement produces a change in the on-and-off pat-

tern—similar to the manner in which a series of light bulbs produces the illusion of movement by changing on-and-off patterns.

Our ignorance about the function of major parts of the cephalopod visual system, such as the optic lobe, prevents researchers from completing a more detailed analysis of cephalopod vision. How the basic eye types could have evolved from the putative primitive type is also unknown, in part because no transitional forms exist, nor do plausible hypothetical intermediate forms exist. An essential difference between vertebrate and invertebrate eyes is that the vertebrate eye photoreceptors face

outwards towards the choroid, whereas in invertebrates they mostly point inwards towards the lens. But for that obstacle we should have been deluged with theories on the original evolution of the vertebrate eye from the invertebrate. As it is, vertebrate visual origins have to be approached with great caution, and...[t]here is nothing indisputable which can be used to explain the origins of the vertebrate eye from an invertebrate organ (Prince, 1956, pp. 334, 348).

All known animals have either verted or inverted retina eyes, and no evidence exists of transitional forms. Invertebrate eyes use either some type of a lens-based eye, such as cephalopods, or a compound eye, as used in trilobites and insects today. All known vertebrates have inverted eyes, and there are no known intermediates between the two.

As Ayoub asked, would “hundreds of thousands of vertebrate species—in a great variety of terrestrial, marine and aerial environments—really see better with a visual system used by a handful of exclusive marine vertebrates? In the absence of any rigorous comparative evidence, all claims that the cephalopod retina is functionally superior to the vertebrate retina remain entirely conjectural” (Ayoub, 1996, p. 20).

Rod and Cone Functions in Vertebrates

The *rods* and *cones* are photoreceptor cells located in the retina used to transduce light into electrical signals. Black-and-white transduction occurs in the rod shaped receptors, and color transduction occurs largely in the cone-shaped receptors (Ryan, 1994). The inverted retina vision system requires light to first pass through the cornea, then through the anterior chamber filled with aqueous fluid, and last, the lens, and the *vitreous humor*. Before reaching the retina, the light passes through the inner retina’s cell layers (which contain a dense array of neural processing cells) and on past the rods and cones until it reaches the posterior (distal) end of these cells—wherein lie the so-called outer cell segments. The outer cell segments contain the photoreceptors, light-sensitive structures including the *photopigment*, where the transduction of light into receptor potentials occurs.

The photopigment family of proteins undergoes physical changes when they absorb light energy. The principal photopigment, opsin glycoprotein, is a derivative of *retinal* (a modified vitamin A molecule). Rods contain a single photopigment type called rhodopsin (rhodo meaning *rose* and opsin meaning *vision*). The cones contain one of three different kinds of photopigments called iodopsins, namely *erythrolabe* (most sensitive to red), *chlorolabe* (most sensitive to green) and *cyanolabe* (most sensitive to blue) (Shier et al., 1999, p. 482).

Vision functions by changes in the retina photopigments molecule caused by light. The molecule has a bent shape (*cis-retinal*) in darkness, and when it absorbs light, isomerization occurs, causing the molecule to form the “straight” form (*trans-retinal*). This causes several unstable intermediate chemicals to form, and, after about a minute, the *trans-retinal* form completely separates from opsin, causing the photopigment to appear colorless (for this reason the

process is called bleaching). In order for the rods and cones to again function for vision, retinal must be converted from the *trans* back to the *cis* form. This resynthesis process, called regeneration, requires that the retina pigment epithelium (RPE) cells be located next to the rod and cone outer segments.

An average of five minutes is required for rhodopsin regeneration in rods, compared to 1.5 minutes for iodopsin regeneration in cones (Tortora and Grabowski, 1996). Excessive light causes blindness in the affected rods and cones until this regeneration process occurs, as shown by the temporary blindness that occurs after watching a very bright light flash from a camera strobe light (Snell and Lemp, 1989).

When rods and cones are stimulated by light, they release neurotransmitters that induce graded, local potentials in both bipolar and horizontal cells. By this means the rod and cone outer segments transduce light into electrical signals. The signals are then carried by the central nervous system neurons to bipolar cells that, in turn, synapse onto the ganglion cells, then to the lateral geniculate body of the thalamus, and, last, to the occipital region of the brain stem, where the information is organized into a useful image (Stoltzmann, 2006).

The Retinal Pigment Epithelium

One of the many reasons for the inverted design is that behind the photoreceptors lies a multifunctional and indispensable structure, the *retinal pigment epithelium* (RPE) (Martínez-Morales et al., 2004). RPE is a single-cell-thick tissue layer consisting of relatively uniform polygonal-shaped cells whose apical end is covered with dense microvilli and basal membrane infoldings. Posterior to the RPE is the vascular choroid layer, and posterior to it is the connective tissue known as the *sclera*. The RPE touches the extremities of both the rod and the

cone photoreceptors, and the microvilli interdigitate with their sides (Steinberg and Wood, 1994).

The photoreceptors (rods and cones) must face away from the front of the eye in order to be in close contact with the vascular choroid, which supplies the photoreceptors with nutrients and oxygen. This arrangement also allows a steady stream of the vital molecule retinal to flow to the rods and cones, without which vision would be impossible (Kolb, 2003). The verted design, on the other hand, would place the photoreceptors away from their source of nutrition, oxygen, and retinal. This design would fail because the rods and cones require an enormous amount of energy for their high metabolism required to function. In addition, due to phototoxicity damage from light, the rods and cones must completely replace themselves approximately every seven days or so. Seemingly simple in appearance, the RPE has “a complex structural and functional polarity that allows them to perform highly specialized roles” (Hewitt and Adler, 1994, p. 58). One of their major functions is to recycle the used retinal from the photoreceptors.

Vision depends on the isomerization of 11-*cis*-retinal to 11-*trans*-retinal in the rods and cones outer segments. Each light photon striking a photoreceptor isomerizes retinal, and billions of photons can strike the retina at any one second. The RPE constantly restores the chromophore to *cis*-retinal from its *trans* configuration caused by photostimulation, permitting visual pigment synthesis and regeneration (Dowling, 1987). The 11-*cis*-retinal must also be regularly replaced to maintain the cycle, a task for which the RPE is critical (Hewitt and Adler, 1994). The RPE manufactures retinal isomerase and other enzymes and stores large quantities of vitamin A to regenerate retinal.

Since RPE cells use enormous amounts of energy and nutrients, they must be in intimate contact with *both*

the photoreceptors and the blood supply (in this case the choroid) to carry out this critical function (Marshall, 1996). Research on the eyes of different species has found that, although major differences among them exist, the RPE shows “little variation” (Kuwabara, 1994, p. 58). The small RPE variations are due to differences in the retina structure, indicating its critical role in the vision of all vertebrates. One study found retinol isomerase in all the major vertebrates tested and was lacking in all three cephalopods tested (Bridges, 1989). Bridges concluded that reciprocal flow of retinoids between the retina and the site of isomerase action in the RPE is a feature common to the visual cycle in all vertebrates (Bridges, 1989).

Phagocytic Role of the RPE

A major role of the RPE is to recycle the used rod and cone outer segment membranes, the cone portion closest to the RPE. The photoreceptors and RPE absorb an enormous amount of light on a continuous basis when the eyes are open. This light is converted largely into heat, requiring a very effective cooling system. The choroidal blood supply directly behind the RPE carries away, not only this heat, but also the relatively large amount of waste products produced by the high level of rod and cone metabolism. Which compounds are allowed to pass through this area is determined by basal membrane receptors. Cones usually contain from 1,000 to 1,200 disks, and rods from 700 to 1,000. The enormous amount of outer segment activity requires continual replacement of these disks (Bok, 1994). As the outer segment lengthens from its base, the oldest membrane, which is at the distal end, is shed in segments of one to three disks at a time. Those that are sloughed off are phagocytized by enzymes stored in RPE lysosomes and its components recycled (Tortora and Grabowski, 1996, p. 467).

The RPE phagocytizes about ten percent of the outer segment disks of nor-

mal rod photoreceptors at its apex and renews the same amount daily (Benson, 1996). To replace those segments that are lost, new outer segment membranes are continually being produced at the outer photoreceptor segment base. Photoreceptor outer segments are renewed at “an astonishingly rapid pace” (Tortora and Grabowski, 1996, p. 467).

After RPE breaks down the ingested material, the free radicals and superoxides produced must be neutralized by superoxide dismutase, peroxidase, and other enzymes (Hewitt and Adler, 1994). This process is continuous, effectively maintaining the photoreceptor’s high sensitivity (Benson, 1996). Bok and Young (1994) summarized this cycle, noting that the

retinal pigment epithelium carries out several functions that are crucial for the normal operation of the visual system. One of these important roles, appreciated for about a decade, is the phagocytosis of rod outer segment debris. This scavenging activity goes on daily at an impressive rate in the normal retina. It can be accelerated to extraordinary levels when outer segments are damaged. Disruption of this phagocytic function may underlie a variety of clinical disorders, some of which result in blindness (p. 148).

RPE microvilli interdigitate and surround the photoreceptor outer segments so as to effectively carry out their phagocytic and recycling role (Bok and Young, 1994).

Nutrient Role of the RPE

The RPE selectively transports nutrients from choroidal circulation to both the photoreceptors and retinal cells. The RPE also helps maintain water and ion flow between the neural retina and the choroid, protects against free radical damage, and regulates retinoid metabolism (Martínez-Morales et al., 2004). The RPE functions similarly to a placenta to ensure that the outer retina

is protected from injurious compounds and yet allows the necessary nutrients to pass into the rod and cone area. RPE cell tight junctions are also part of the outer blood-retinal barrier, preventing diffusion of even small molecules into the vitreous humor and ensuring that the metabolites required by the outer retina can move to where they are needed when they are needed (Hewitt and Adler, 1994).

To ensure that enough of the needed nutrients pass the RPE barrier, the basal membrane is highly infolded to produce more surface area. This role is critical because the rods and cones require a greater blood supply than any other bodily tissue (Hewitt and Adler, 1994). This is important because of the high level of metabolism due to the complex chemistry required for vision, which necessitates a higher level of oxygen and nutrients. The RPE also synthesizes and secretes various extracellular matrix molecules that must be produced near the location where they are to be used.

If the photoreceptors were anterior to the neurons, as in the verted design, the blood supply would have to be either directly in the light path of the receptors or on their side, which would reduce enormously the number of photoreceptors used for sight. If the pigment epithelium tissue were placed in front of the retina, sight would be seriously compromised. The verted design would make vision impossible because the photoreceptors must be embedded in the retinal pigment epithelium to obtain the nutrients required to function.

Müller Cells Function as Optical Fibers

Placing the retina neural components in front of the photoreceptors does not produce an optical handicap for yet other reasons (Land and Nilsson, 2005). One is that the neural elements are separated by less than a wavelength of light. Consequently, very little or no scattering or diffraction occurs, and the

light travels through this area as if it were at near-perfect transparency.

The Müller cells (which are radial glial cells) in front of the retina have both shape and optical properties that contribute to optimizing light transferral and reducing light scatter (Franze et al., 2007). Müller cells “have an extended funnel shape, a higher refractive index than their surrounding tissue and are oriented along the direction of light propagation” (Franze et al., 2007, p. 8287). The effect provides a “low-scattering passage for light from the retinal surface to the photoreceptor cells,” functioning as fiber optic plates that are effective for low-distortion transfer of light images. Franze et al. (2007) concluded that cells thought to interfere with light transmission are actually highly effective in reducing light scatter and distortion, helping to produce a sharp image.

The Macula

The importance of the RPE is indicated by the fact that one of the most common causes of blindness in the developed world, macular degeneration, is the result of RPE deterioration (Zhang, et al., 1995). In this disease the eye’s macula loses its ability to function, causing major central vision loss. Without the nourishment and waste removal role of the pigment epithelium, retina cells will also die. Among the other diseases affecting the macula is *central serous retinopathy*, an ion pump malfunction and/or a result of choroidal vascular hyperpermeability.

Detached Retina and the Role of Pigment Epithelial Cells

The retina is connected to the RPE largely by the interphotoreceptor matrix. When the retina pulls away from the RPE at the interphotoreceptor matrix area, a *detached retina* results (Zamir, 1997). The RPE can then no longer effectively function to regenerate the rods and cones, causing vision to become distorted, and eventually the death of

significant levels of retina tissue. Progressive detachment can often be halted by laser therapy, a procedure that is only minimally invasive because laser light is able to pass through the cornea and the lens without damaging them. Laser therapy stimulates the migration of the RPE cells, inducing the pigmentation line to form.

Functions of the Pigment

The many diverse functions of the retinal pigment epithelium cells that are “essential for the normal functioning of the outer retina” include producing a black pigment called *melanin* (Hewitt and Adler, 1994, p. 67). The melanin functions to absorb most of the light not captured by the retina, preventing the reflection and scattering of light within the eyeball. This inhibits light from being reflected off the back of the eye onto the retina, preventing degradation of the visual image and ensuring that the image cast on the retina by the cornea and lens remains sharp and clear.

Yet another function of the pigment is to form an opaque screen behind the optical path of the photoreceptors. This light absorptive property of the pigment is critical to maintaining high visual acuity. For this reason, normal retinal function requires that the RPE and photoreceptors be in close proximity. Lack of the pigment, as in albinism, can cause a variety of problems such as *fovea hypoplasia*, an abnormal routing of the optic nerve (Oetting and King, 1999; Lyle et al., 1997; Jeffery and Williams, 1994). As a result of this and other factors, albinism victims lack detailed central vision (Snell and Lemp, 1989; Williamson, 2005).

The Retina Pigment Epithelium’s Role in Development

RPE is also critical for normal vertebrate eye development. A series of reciprocal cellular interactions during vertebrate eye development determine the fate of the eye components, and the

presence of the RPE is required for the normal development of the eye *in vivo*. Its presence early in development is necessary for the correct morphogenesis of the neural retina (Raymond and Jackson, 1995, p. 1286).

The RPE actually plays a succession of roles during embryonic development, including trophic influence, transport functions, retinomotor response, and phagocytic and inductive interaction (Coulombre, 1994).

Does the Backward Design Block Light?

Nerve cell fibers and the small branches of the central retina artery and vein produce minimal hindrance to light reaching the photoreceptors because most cells are 60 to 70% water and, consequently, are largely transparent. When viewed under the microscope, most cells are largely transparent. It is for this reason stains, such as Eosin-Y and Hematoxylin 2, are required to better visualize the various cell parts. Myelin, an opaque whitish lipid that coats nerve axons, would block much light, but, in contrast to most peripheral nerves, nerve fibers in front of the retina are not myelinated. Furthermore, the larger blood vessels and nerve fibers skirt around the *area centralis*, where visual acuity is most important (Gregory, 1976). The vertebrate eye is highly effective in spite of the retina reversal because it is a precise visual instrument designed to function with the rods and cones facing away from the light.

The tissues intervening between the transparent humors of the eye cavity and the optically sensitive layer are microscopically thin. The absorption and scatter of light is ordinarily minor, and functional impairment seldom serious.... Red blood cells are poor transmitters of light, but when moving single file through capillaries can cause only a negligible shading

of the light sensors (Williams, 1992, p. 73).

These facts have forced Dawkins to note that many

photocells point backwards, away from the light. This is not as silly as it sounds. Since they are very tiny and transparent, it doesn't much matter which way they point: most photons will go straight through and then run the gauntlet of pigment-laden baffles waiting to catch them (Dawkins, 1996, p. 170).

Moving shadows produced by the venules and arterioles are also highly functional because they produce momentary darkness to aid in the rod and cone regeneration. Constant bright light would excessively bleach the photopigment, and the lower light achieved by the existing design allows their regeneration.

Other Possible Designs

A major concern when critiquing the existing vertebrate retina design involves speculation on the quality of vision that would result from another design. No evidence exists that a verted human retina design, as in octopi, would result in better vision, and it would likely be worse. Comparisons of different eyes are difficult to make because, although the quality of the image projected on the retina can be evaluated by a study of the lens system's optical traits, direct knowledge about the actual image produced in the brain is lacking.

If the retina were reversed, the retinal pigment epithelium or its analog and its cellular support system would have to be placed either in front of the photoreceptors or on their side. Both of these approaches are clearly inferior to the existing vertebrate system, which produces superior sight for terrestrial animals. If located in front of the retina, depending on the transparency of these cells, this design could prevent most light from reaching the photoreceptors.

If the RPE functioning cells were located on each side of the rods and cones, as in the cephalopods, primarily only the sensory cell face would be able to respond to light. Octopi use support cells located next to the light-sensitive cells called rhabdomeric receptors that use photopigments containing microvilli (Land and Nilsson, 2005). The support cells also require increasing the space between the photoreceptors, further decreasing light able to strike the photoreceptors, and consequently lowering vision resolution. Prince (1956) even claims the cephalopod's side design "is protective and shields the receptors from excess light" (p. 343). Opaque wastes would accumulate in the light path, and the presence of required nutrients would further diminish the amount of light reaching the photoreceptors. Recycling the outer segments to allow rapid regeneration of the photoreceptors would also be a major problem if the photoreceptors faced the vision light path line. Verted designs produce the following concerns:

Should the disk end of the rods and cones be reversed in direction so as to face the light...we would probably have a visual disaster. What would perform the essential function of absorbing the some 10,000 million disks produced each day in each of our eyes? They would probably accumulate in the vitreous humor region and soon interfere with light en route to the retina. If the pigment epithelium layer were placed on the inside of the retina so as to absorb the disks, it would also interfere with light trying to reach the rods and cones. Furthermore, the pigment epithelium, which is closely associated with the disk ends of the rods and cones, also provides them with nutrients for making new disks. The epithelium gets its nutrients from the rich blood supply in the choroid layer next to it. In order for the pigment epithelium to function

properly, it needs this blood supply. To put both the pigment epithelium and its choroid blood supply on the inside of the eye, between the light source and the light-sensitive rods and cones, would severely disrupt the visual process (Roth, 1998, p. 109).

Although higher visual acuity may improve night vision, in humans it would result in difficulty seeing during daylight hours, which would not be functional for persons that must work in normal human-light environments (Sjostrand, 1989). Actually, a case can be made that *more* light blockage of the retina would be functional. Many persons must wear sunglasses because normal outdoor light is often too bright. In a review of the literature, Young (1992) found that excess solar radiation can be a serious health problem, and may

explain the distinctive global pattern of age-related cataract among human populations—the risk of cataract depends on where one lives on the surface of the earth....Current evidence provides the basis for the design of protective lenses that minimize the hazards of sunlight exposure without significantly interfering with vision. The prescription has two components—one to protect the lens, the other to protect the retina....Use of sunglasses...should begin early in childhood and be continued throughout the life span whenever exposure to bright sunlight is desirable or necessary. Radiation damage to delicate ocular structures can occur at any age and tends to be cumulative (pp. 335-357).

Albinos lack iris pigment, requiring them to wear sunglasses in daylight because even moderately bright light may severely adversely affect their vision (Tortora and Grabowski, 1996, p. 461). Even blue-eyed persons are at a disadvantage because the blue pigment allows in more light than the darker iris pigments. Consequently, they suffer from more vision problems (Young, 1992). Being able to

effectively read by very dim light may be an improvement in some situations, but since most human activities occur during daylight hours and darkness is functional to induce sleep due to pineal gland activity, the existing system appears to be the most effective.

Furthermore, although the light yellow tint of the eye lens filters out some ultraviolet light, the inverted eye design serves to filter out much of the remaining ultraviolet light. The incoming light must pass through the overlying neural components and blood vessels, and the penetrating power of ultraviolet light is markedly inferior to white light (Lumsden, 1994). The verted eye is used in animals such as the octopus, which live underwater, where most of the ultraviolet light is filtered out. Consequently, they have less need for this protection. Given the role of the pigmented epithelium, it is clear that the existing design is ideal.

Conclusions

A review of research on the vertebrate retina consistently concludes that each design is perfectly suited for the environment the organism normally lives in—even the system used by the most advanced cephalopods (Bergman, 2000; Bergman and Calkins, 2005; Wieland, 1996; Marshall, 1996). The design maximized for life in our environment would no doubt function poorly in another environment, such as that experienced by undersea bottom dwellers. The RPE metabolic machinery is “essential for the normal functioning of the outer retina [and] because of the nature of these interactions, it is essential that the RPE and photoreceptors be in close proximity” for normal retina function (Hewitt and Adler, 1994, p. 67). This review supports Hamilton’s conclusion that

instead of being a great disadvantage, or a “curse” or being incorrectly constructed, the inverted retina is a tremendous advance in function

and design compared with the simple and less complicated verted arrangement. One problem amongst many, for evolutionists, is to explain how this abrupt major retinal transformation from the verted type in invertebrates to the inverted vertebrate model came about as nothing in paleontology offers any support (Hamilton, 1985, p. 63).

Rather than being fired, our camera designer would no doubt be promoted for utilizing a less obvious but far more functional design. It is clear that “eyesight is a compelling testimony to creative design” (DeYoung, 2002, p. 190). This short review covers only a few of the many reasons for the superiority of the existing mammalian retina design. Gratitude rather than impertinence seems the more appropriate response to its ingenious design.

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Notes from the Panorama of Science

The Lesser Light to Govern the Night: Further Notes on Light Production in *Photinus pyralis*

Introduction

In a previous Panorama of Science Note (Armitage, 2008), some of the anatomical structures of the lantern tissues involved in bioluminescence in the firefly, *Photinus pyralis*, were discussed. This note delves into further detail of these features.

Fireflies use molecular oxygen (and possibly hydrogen peroxide that they synthesize) together with nitrogen (in the form of nitrous oxide that they also synthesize) via an ATP, calcium, and magnesium-mediated luciferin/luciferase reaction to produce the excited-state intermediate oxyluciferin that releases photons of light (Carlson, 2004; Chiradella and Schmidt, 2004; Timmins et al., 2001) in abdominal tissues called the lantern (Figures 1 and 2). They do this to communicate with other insects using a light-signaling language to convey one of several messages, such as their availability for mating, abandonment of flight (i.e., “I have landed”), or that they are trapped by something (Chiradella, 1998). Females of differing species, acting as predators, can accurately reply to the flashing of interested males to attract them (Lloyd, 1975; refers to them as “femmes fatales”). Although signaling (i.e., flashing) seemingly costs males very little in energy, flashing does increase their predation vulnerability (Woods et al., 2007).

It has been reported that protein shape changes during protein synthesis of the luciferase enzyme in fireflies can actually translate into changes in the wavelengths of light emitted (Ando et al., 2008; Biggley et al., 1967; Nakatsu

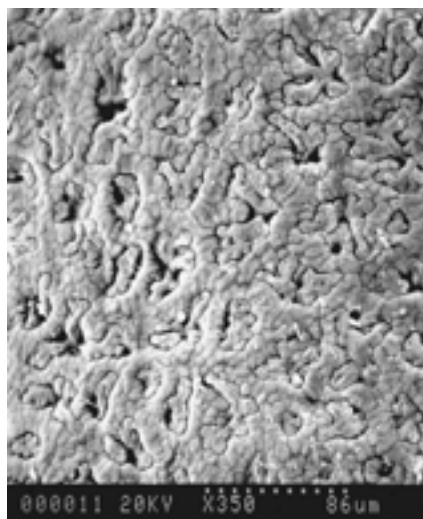


Figure 1. Scanning electron micrograph (SEM) of firefly lantern tissue lying just below the translucent sternite (or outer cuticle plate) of the firefly exoskeleton. The plate has been removed to reveal the tissue. It is within the lobes of this tissue that chemical light is produced in the firefly. Magnification is 350X, and the dotted scale bar is 86 micrometers (microns)—about the thickness of a human hair.

et al., 2006). (Other unknown factors may also alter the shape of the luciferase molecule.) Fireflies emit different colors (green to yellow to red), depending upon (and possibly controlled by) pH levels at the reaction sites and/or the substitution of a single amino acid in the production of luciferase, the enzyme that mediates the reaction to produce an excited state of oxyluciferin used for bioluminescence. Further discussion on this topic will appear in a future paper. Further-



Figure 2. A higher magnification SEM of the tissues from Figure 1. Note the “rosette” or flower-petal style configuration of the photocytes (light-emitting cells) surrounding the open end of the tracheal tube, which delivers atmospheric gases to the photocytes for use in the light-producing reactions. Magnification is 1,500X, and the dotted scale bar is 20 microns.

more, the duration of firefly flashes are actually tightly controlled light pulses that are species-specific varying by only tens of milliseconds (Barry et al., 1979). Moreover, the flashes that are comprised of multiple pulses are also mere milliseconds in length, while single pulses are even shorter in duration (Carlson, 2004; Cratsley, 2004; Lewis et al., 2004).

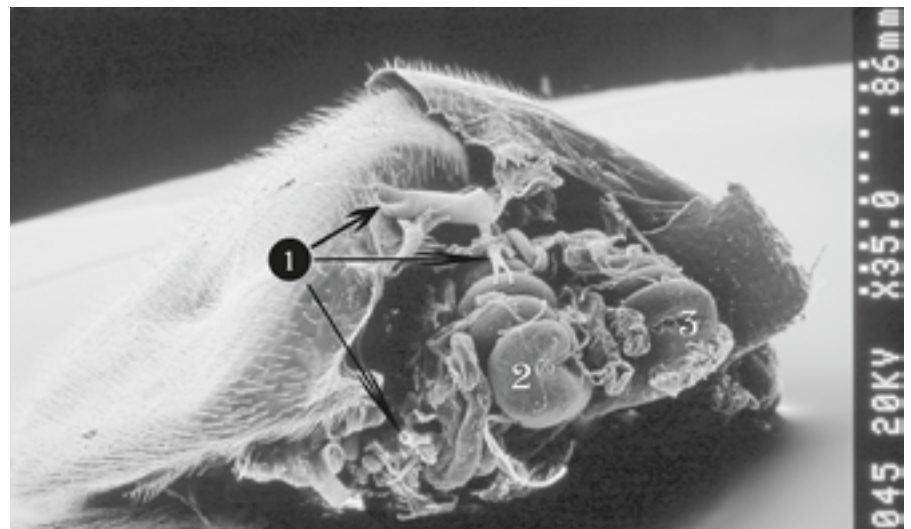
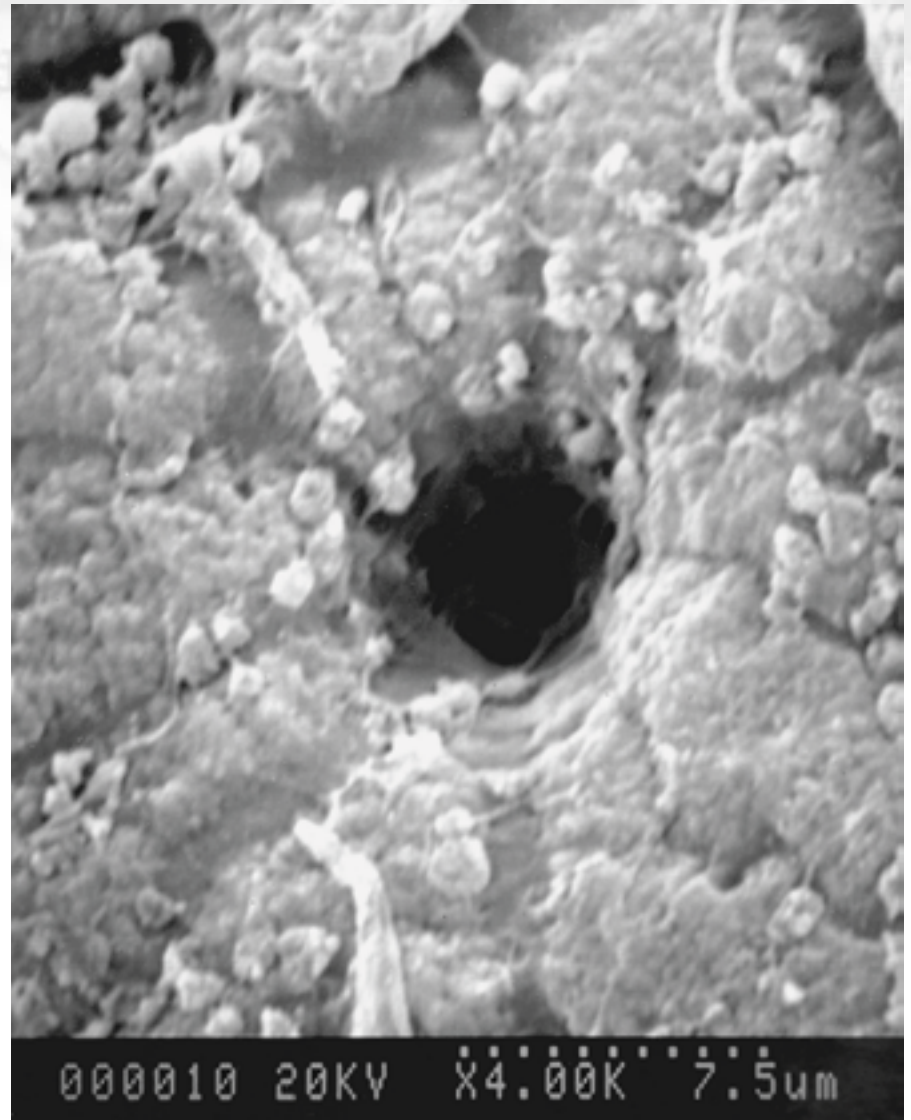
In the Orient, male fireflies resting on tree leaves flash in unison. This serves to light up complete trees (and groves of

Figure 3 (*right*). A close-up image of the tracheal tube from Figure 2. Magnification is 4,000X, and the dotted scale bar is 7.5 microns.

Figure 4 (*below right*). A side view of a firefly abdomen, which has been mechanically split in half. The ventral (bottom) side of the insect is facing upwards. Note the hairlike spines pointing up (on the outside of the cuticle below which the lantern tissues lie). Also see the large tracheal (air delivery) tubes (black arrows from #1) on the dorsal and ventral sides. The spiral structures labeled 2 and 3 are probably “nuptial packets” or sperm-carrying tubes that are exchanged with females during mating. Magnification is 35X, and the dotted scale bar is 0.86mm.

trees) with synchronized flashes (Ghiradella, 1998). In fact, this synchronized flashing mechanism is so complicated that the Ohio State University Department of Electrical and Computer Engineering produced a laboratory exercise related to the firefly for students (Chuang et al., 2004). Their “simplified kit” contains 13 different electrical components, including a printed circuit board, switches and phototransistors, and other components, plus a sophisticated software program to run the simulation (Chuang et al., 2004).

When assembled and programmed, these kits “see” other nearby flashes and adjust their flashing to synchronize with the others. Eventually, after some period of time, all of the flashing is synchronous. The kit, however does not adjust the frequency of the flashes to account for changing environmental conditions (as performed by fireflies and mentioned above), nor does it make “decisions” based on the introduction of females, males, or predators into the environment. It does not fly away or otherwise move, feed, copulate, excrete waste,



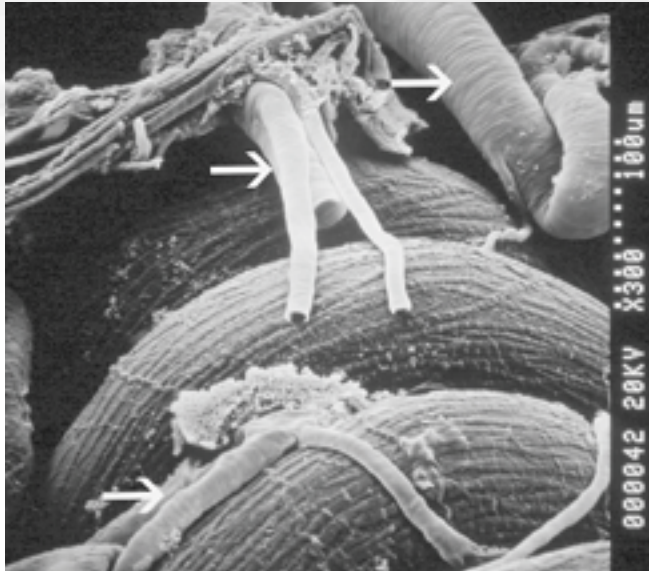


Figure 5. Magnified SEM of some tracheal tubes (white arrows). Some are traveling up/down and some side to side. Magnification is 300X, and the dotted scale bar is 100 microns.

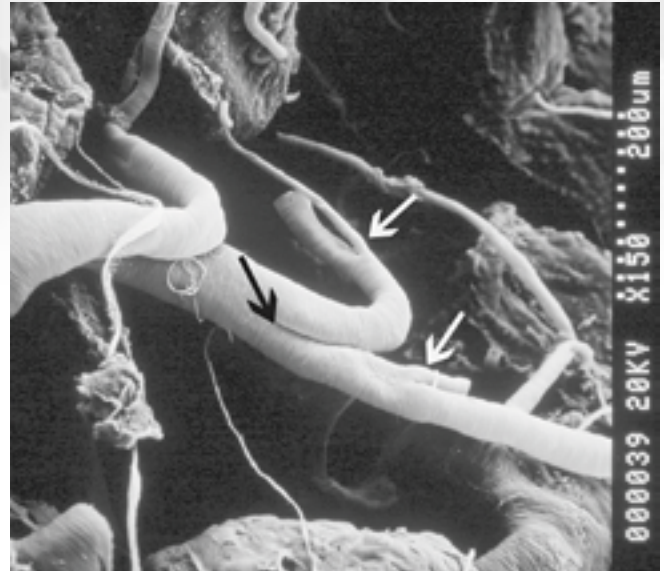


Figure 6. SEM of some tracheal tubes that have bifurcated, or split into separate forks. The black arrow is pointed at a $\frac{1}{2}$ reduction split, while the white arrows show even smaller forks branching off. Trachea will subdivide in this fashion into smaller and smaller branches in order to deliver atmospheric gases deep into firefly tissues. Magnification is 150X, and dotted scale bar is 200 microns.

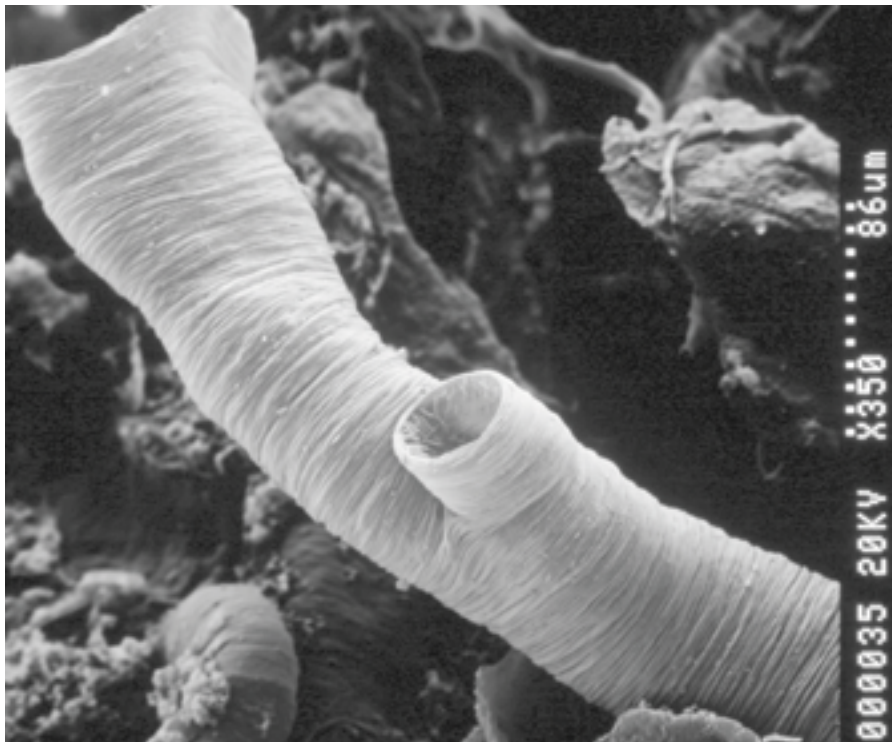


Figure 7. SEM of a tracheal tube showing bifurcation and hairlike cilia in the inner space of the tracheal branch. Note also the outer ridges of the tubes that run perpendicular to the tube length. Magnification is 350X, and dotted scale bar is 86 microns.

lay eggs, or perform any of the other myriad things that fireflies do routinely, in spite of being highly engineered to “see” flashes and adjust accordingly. This research has documented the hyper design used by fireflies.

Insect Respiration System

Insects respire via a very complicated system of tracheae, or tubes (Figure 3) that infiltrate deeply into tissues by branching repeatedly into smaller and smaller branches (Mill, 1998). These tubes connect to the atmosphere via a set of valves located on the exoskeleton of the insect (called *spiracles*) that have specialized filters, as well as opening and closing muscles designed specifically for the control of gas exchange with the environment (Mill, 1998; Persijn et al., 2006). Spiracles will be discussed in a later paper. Tracheae bring in atmospheric oxygen, nitrogen, and wa-

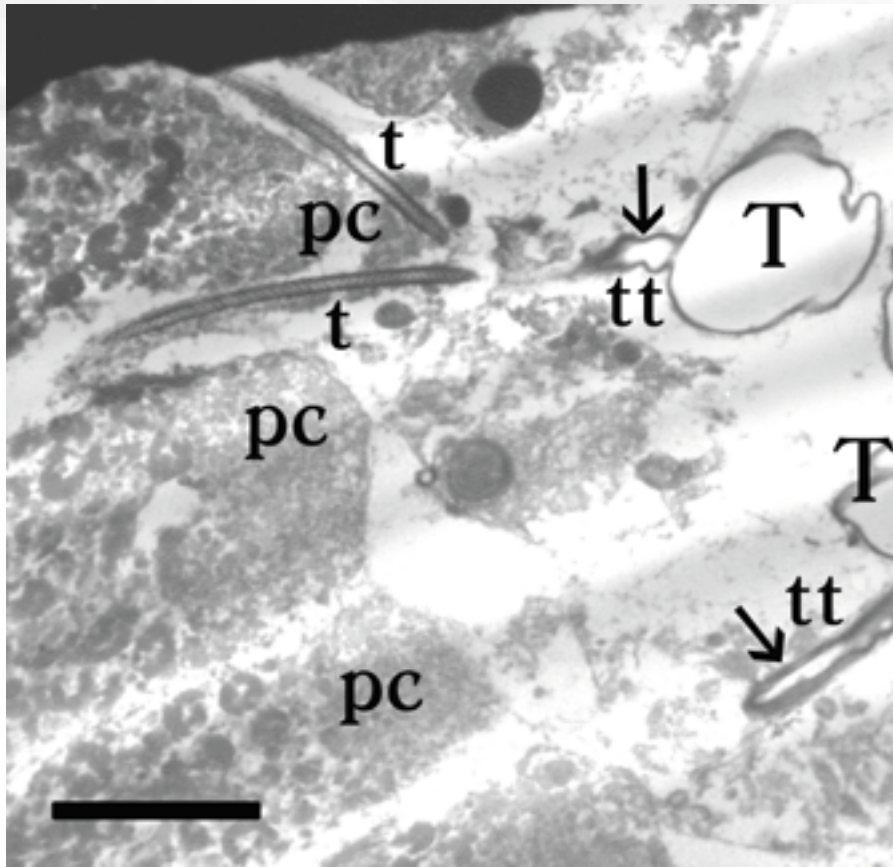


Figure 8 (*left*). Transmission electron micrograph (TEM) of a thin section through the firefly lantern tissues. Labeled structures include the photocytes (pc), where light is produced (within the peroxisomes); large trachea (T), which is shown at the center of the rosette of lantern tissues; tracheal tubes (tt—black arrows), which branch off from the trachea and give rise to smaller branches that move deeper into lantern tissues; and tracheoles (t), the tiny tubes that travel between photocytes. Magnification is 2,500X, and scale bar is 9 microns.

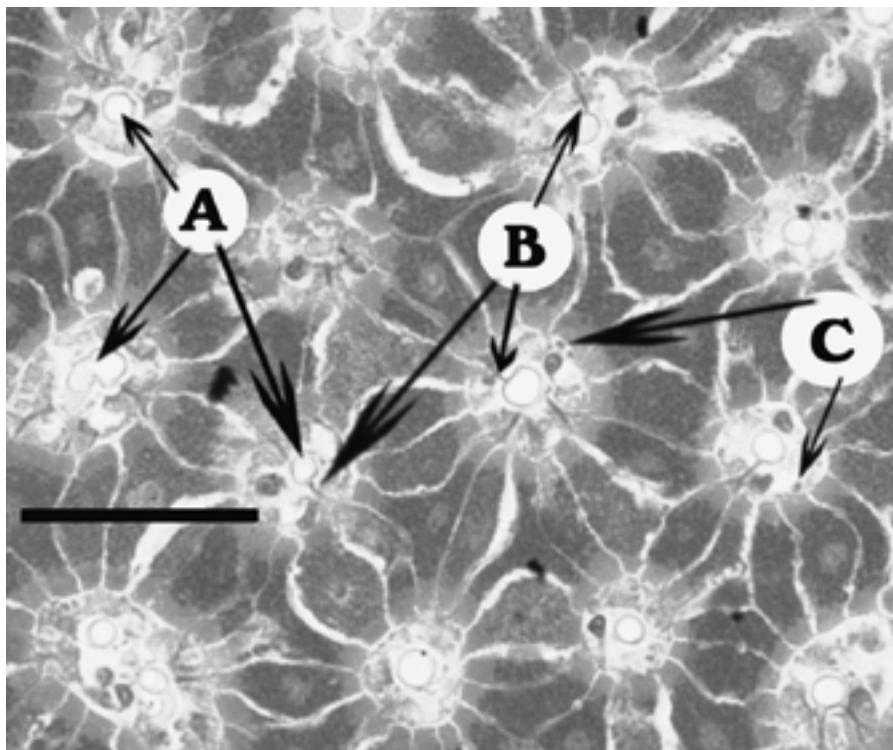


Figure 9 (*below left*). High magnification light micrograph of a thin section through the lantern tissues. Labeled structures include large central tracheae at the centers of each rosette (black arrows from A); smaller tracheal tubes, which move deeper into tissues (black arrows from B); and nerve endings, which are located in the end cells surrounding the tracheae, thus showing that nerves do not touch the actual photocytes (black arrows from C). Magnification is 500X, and scale bar is 65 microns.

ter vapor plus other gases and excrete unwanted gases (such as CO_2). The tracheal system in the lantern tissues of fireflies generally traverses from large trunks near the dorsal surface and then extends to the ventral side (Ghiradella, 1977; 1978). (See Figures 4–5 for examples of the anatomy of these large trunks). In fireflies, the tracheae divide and subdivide (Figures 6–7). At one point, before they approach the light-emitting cells (photocytes), they branch into tracheal twigs and, finally, into tracheoles of finer and finer diameter until they terminate between the photocytes to supply the light-emitting tissue with oxygen (see Figure 8, labels “tt” and “t”).

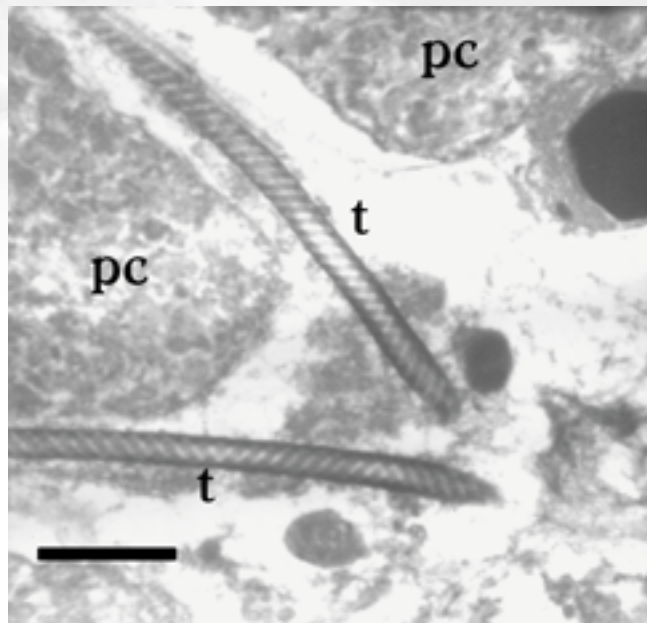


Figure 10. Very high magnification TEM of a thin section through the firefly lantern tissues. Labeled structures include the photocyte (pc), where light is produced (within the peroxisomes); and tracheoles (t), the tiny tubes that travel between photocytes. The two unmarked dark ovals just next to the tracheoles may be nerve endings that trigger the light reaction. Magnification is 6,300X, and scale bar is 1.5 microns.

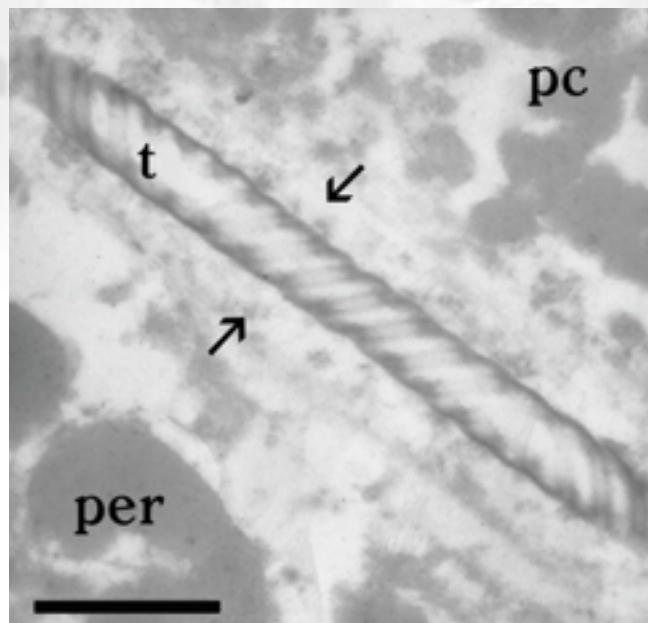


Figure 11. Ultra high magnification TEM of a thin section through the firefly lantern tissues. Labeled structures include the photocyte (pc), which contain the peroxisomes; a single tracheole (t) traveling between two photocytes; and a peroxisome (per), where the light reaction takes place. The tissue upon which the tracheole travels (marked with black arrows) is highly specialized tissue that is often heavily populated with mitochondria. Magnification is 10,000X, and scale bar is 900 nanometers.

This network of ducts is much denser in insects that have higher requirements for oxygen, such as the firefly (Ghiradella, 1998; Mill, 1998; Noiro et al., 1982).

As mentioned, tracheoles terminate in the light-emitting tissues at a central point around which a “rosette,” or flower-shaped cylinder of photocytes, is arranged (see Figures 3 and 9). Although the mechanism that controls the complex flashing of the firefly “lantern” has been debated for years, electron microscope study of the anatomy shows that nerves do not terminate on photocytes, but rather *before* the photocytes—onto the tracheal tubes just anterior to the photocytes (Smith, 1963; Ghiradella, 1977; 1978; 1998; Ghiradella and Schmidt, 2004). Greenfield (2001) wrote that the

molecular oxygen needed by the biochemical reactants is delivered

by a network of tracheal arborizations extending throughout the light organ (lantern). However, the actual means by which oxygen quickly reaches the reactants packaged within specialized photocytes and the specific event(s) triggered by neural action have not been identified; termination of axons away from the photocytes has exacerbated the latter problem (p. 992).

It is likely that nerves are controlling the actual delivery of water vapor, oxygen, and nitrogen to the reaction site and do not directly control the photocytes themselves. Therefore, the complex series of firefly flashes manifested by fireflies may not be controlled by neural impulses sent directly to photocytes but rather by impulses that control the concentrations of these gases within the tracheal system (Aprille et al.,

2004; Greenfield, 2001; Ghiradella and Schmidt, 2004; Timmins et al., 2001). The tracheal system therefore could (and possibly must) employ a “forced air” system whereby some coordination of airflow takes place, making it more robust than simple passive diffusion.

Research on tracheae and tracheoles, discussed at significant length in the literature, has documented the fine structure of the duct wall and the taenidia or external ridges. These external ridges fortify these tubes and travel lengthwise along the tracheoles in a helical fashion (Beams and Anderson, 1955; Buck, 1948; Ghiradella, 1977; 1978; 1998; Ghiradella and Schmidt, 2004; Kluss, 1958; Noiro et al., 1982; Peterson and Buck, 1968; Smith, 1963), (see Figures 7, 10 and 11). Micropapillae are reported to exist on some tracheoles between the taenidia, but no micropapillae were

found in *Photinus pyralis* specimens examined in the present study. Instead what were found were many scores of tiny cilia-type projections on the tracheae's inside surface, which extended from the internal tracheal wall well into the trachea lumen (Figures 7 and 12). No such cilia-type structures are discussed anywhere in any of the *Photinus pyralis* tracheae literature listed in the references (below). Therefore, these might be heretofore-unknown structures reported here for the first time.

It is not known if such cilia-type structures within the tracheae are controlled by the nerves terminating into the tracheal end cell immediately adjacent to each photocyte, but such control could explain the rapidity of the funneling of atmospheric oxygen and nitrogen into the photocytes to cause the reaction and flashing that occurs in milliseconds or tens of milliseconds. This also might explain why the flashing and pulsing of the firefly lantern are so rapid.

More attention will be devoted in a future paper to the photocytes that contain a differentiation layer of specialized mitochondria and the peroxisomes, which actually produce the light.

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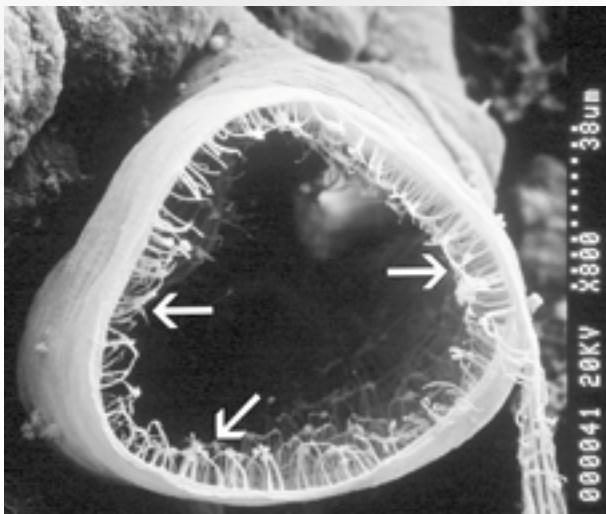


Figure 12. SEM of a sectioned tracheal tube showing the many hairlike cilia in the inner space (lumen) of the tracheal branch. It is this author's contention that these cilia assist in the rapid delivery of atmospheric gases to the photocytes and that they are controlled by the nerve endings in the tracheolar end cells. Magnification is 800X, and dotted scale bar is 30 microns.

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Letters to the Editor

The policy of the editorial staff of CRSQ is to allow letters to the editor to express a variety of views. As such, the content of all letters is solely the opinion of the author, and does not necessarily reflect the opinion of the CRSQ editorial staff or the Creation Research Society.

Young Earth, Old Universe?

Individuals who are concerned to find harmony between observations of the physical universe and related specifications in the Bible are deeply indebted to Danny Faulkner for preparing, and to CRSQ editors for publishing, the treatment on stars that was featured in the Fall 2007 issue of CRSQ.

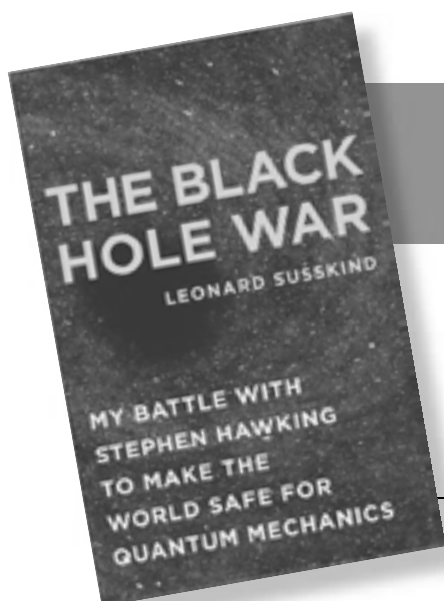
In the first paragraph of the conclusion section, Dr. Faulkner states, “A very small minority of recent creationists believe that the Creation Week refers to the creation of the earth and its biosphere rather than the entire universe” (p. 83). By “recent creationists” he evidently specifies individuals who place the Biblical Creation Week less than 10,000 years ago. The “very small minority” specification may indicate that his contacts have been largely limited. Since

major producers of literature dealing with Biblical creationism, such as the Creation Research Society, have been committed to favoring the concept of the existence of the entire physical universe to no more than the time span that can be established from chronological data in the Bible (young-earth model), readers of creationist literature have had little opportunity to evaluate a cosmology that places no constraint on the age of the universe while adhering to the definitions in Genesis 1:8–10, according to which “heaven” and “earth” are features of the surface of planet Earth, features which originate on the second and third days of the Creation Week. (Note that the “without form” [second verse] state of the planet terminated in

the third day of Creation Week, and the “void” [second verse] state terminated with plant life in the latter part of the third day [verses 11 and 12], and animal life over the fifth and sixth days [verses 20–31].)

Designating creationists who consider no restriction from the Bible as Class I, those who consider the Bible creation account as specific to only planet Earth as Class II, and as specific for the entire universe as Class III, I suspect that at present Class II may be a minority with respect to Class III, but not a “very small minority,” in a poll that might be taken.

Robert H. Brown
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Book Review

The Black Hole War

by Leonard Susskind

Little, Brown & Co., New York, 2008, 470 pages, \$28.00.

The Black Hole War is written as a popular review of the controversy between the author, a theoretical physicist at Stanford University, and Stephen Hawking, a well-known British physicist. Author Susskind tells the progress of the war, or debate, in a delightful and humorous way. The physics concepts involved in quantum mechanics, relativity, string, and membrane theories, while superficial of necessity, are done in an understandable manner. A few formulas are used, but most concepts are illustrated.

The discussion centers on the questions of the evident conflict between quantum physics and relativity, particularly as applied to black holes. The basic question is whether information is irretrievably lost when absorbed into a black hole. Stephen Hawking maintains that it is lost, whereas Susskind opposes this idea. Throughout the book, Susskind relates the pros and cons for each point of view.

The discussion raises a number of questions that Creation scientists need to consider. Susskind discusses entropy at some length. While he gives a mathematical definition of entropy and discusses the second law of thermodynamics,

he uses information entropy as a basis for his concepts and states that “entropy is hidden information” (p. 133). This differs somewhat from the usual definition of information entropy: how much information is missing from a message. Information itself is usually considered to be a message that conveys meaning. In any event, the author states that “entropy *always* increases” (p. 141). Thus, the application of the macroscopic definition in the original concept of the second law of thermodynamics still holds.

A question I have had for some time, and that surfaces here, is why scientists insist on discussing religion in scientific books and discussions. Although the author claims to be “a scientist with not a religious bone in [his] body,” he states, on the very next page, that “Darwin’s idea of natural selection ... replaced the magic of creation with the law of probability and chemistry” (pp. 275-276). He also indicates that debates on intelligent design are not scientific. The author insists on making such comments. Are these scientists trying to convince themselves that God doesn’t matter? Or are they trying to convince their peers that they don’t believe in a Creator? If they are not religious, why do they insist on including their religion of evolution,

stating that only natural processes can be considered in describing origins and the natural world?

Another concept that the author discusses in some detail is the holographic principle, which states, “The three-dimensional world of ordinary experience ... is a hologram, an image of reality coded on a distant surface.” However, if my holographic body is struck by a holographic car, I have difficulty in imagining holographic pain being projected into my consciousness. But does this principle create difficulties for the creationist? No, it doesn’t. Reverting to the law of first principles, we can assert that, if this idea is true, God placed this information on the inner surface of the boundary of the universe, and supplies the light necessary for projecting the images encoded on the surface.

The author comments a number of times on scientists’ need to revise their thinking. This includes relativity, quantum mechanics, and more recently string and membrane theories. I suggest that secular scientists also rewire their thinking to include “in the beginning God.”

Carl Stebner

Minutes of the 2008 Creation Research Society Board of Directors Meeting

The forty-fifth annual meeting of the Creation Research Society (CRS) Board of Directors (BOD) was held on 12, 13, and 14 June 2008 at the Courtyard Marriot Hotel, Florence, Kentucky. The meeting site was chosen to allow interaction with Answers in Genesis (AIG) board members, who invited us to dialog and visit the AIG Creation Museum.

On Thursday, 12 June, individual committees (lab, constitution, publication, and Internet) met in the afternoon.

The first part of the all-board meeting convened at 1900 hours. Present were: Mark Armitage, Ted Aufdemberge, Eugene Chaffin, Don DeYoung, Russ Humphreys, Dave Kaufmann, Gary Locklair, Mike Oard, Ron Samec, Glen Wolfrom, and staff members Kevin and Diane Anderson. Guests present: Jerry Bergman, Wayne Frair (emeritus BOD), and George Howe (emeritus BOD). Unable to attend: Danny Faulkner, Lane Lester, John Reed, and David Rodabaugh.

President Don DeYoung provided a meeting orientation and outlined some history of the CRS. He reminded members that we have a rich heritage along with a responsibility to current members to provide excellent leadership and stewardship of society assets.

The 2007 minutes were approved as published in the CRSQ.

Recording secretary Dave Kaufmann reported that the following were elected to a three-year term on the BOD: Ted Aufdemberge, Danny Faulkner, Mike Oard, and David Rodabaugh.

Financial secretary Ted Aufdemberge provided a financial process

(right) Former Board member Dr. Wayne Frair visits with Board President Dr. Don DeYoung.

(below) General Meeting of the CRS Board of Directors.



overview and instructions to committees regarding budgets.

The lab committee report by chairman Don DeYoung indicated that our lab facilities at the Van Andel Creation Research Center (VACRC) are hosting a number of exciting projects. CRS facilities are being used to advance the understanding of the creation model. Of particular note: Mark Armitage has relocated his electron microscope lab to VACRC in Chino Valley. This provides the CRS with additional ongoing research and an educational outreach. Kevin and Diane Anderson continue as lab director and administrative assistant respectively. Kevin has moved from a full-time position to a part-time position this year. The report further stated that the recent VACRC facility upkeep included painting, shingle

replacement, and new heating/cooling units. A Prescott, AZ, water pipeline is planned along the roadside perimeter of the VACRC (CRS land). We have contracted an attorney to protect our property while cooperating with local authorities. Mark Armitage will be the board's liaison in this matter. The lab committee submitted an expense budget of \$111,000 for 2008–2009.

The constitution committee report by chairman Dave Kaufmann addressed two major issues: CRS archives and the revision of several position descriptions. Initially the BOD passed the following proposal: Since Concordia Historical Institute and Iowa State University will no longer take any more CRS archival materials, the BOD designates Bryan College, Dayton, TN, as our new archival repository for future deposits by any CRS members. N.B. This proposal was

later rescinded and tabled for possible action at next year's meeting. Gary Locklair will be visiting the current archives and discussing alternatives in August. The BOD approved the revised position descriptions for the treasurer, financial secretary, and membership secretary and created a new position of assistant to the CRS treasurer, which for the time being is a part-time, paid position. The constitution committee submitted an expense budget of \$0 for 2008–2009.

Treasurer Gary Locklair reviewed the preliminary financial figures for 2007–2008. In 2007 the BOD approved an expense budget of \$306,838. Because income was down slightly during the year, committees were able to trim their expenses to meet a balanced budget (special thanks to the lab committee in this area). Projections for 2007–2008 indicate that we should again operate in the black with expenses of \$292,773 and income of \$293,393. Treasurer Locklair commended the good stewardship of the board and individual committee chairmen. He reported on a meeting he had with the financial secretary and professional staff that has resulted in the streamlining of several financial procedures. The treasurer submitted an expense budget of \$14,000 for 2008–2009 on behalf of the executive committee.

Tim Dudley, president of New Leaf Publishing (Master Books), and Laura Welsh, addressed the BOD about joint publishing possibilities.

The first part of the all-board meeting was adjourned at 2130 hours.

On Friday, 13 June, individual committees (membership, periodicals, research, executive, and finance) met in the morning. The afternoon was spent visiting AIG's Creation Museum. The evening was spent in dialog with AIG staff and board members (Ken Ham, Mark Looy, Jason Lisle, et al.)

On Saturday, 14 June 2008, the second part of the all-board meeting convened at 0830 hours. Present were: Mark Armitage, Ted Aufdemberge, Eu-

gene Chaffin, Don DeYoung, Danny Faulkner, Russ Humphreys, Dave Kaufmann, Gary Locklair, Mike Oard, Ron Samec, Glen Wolfrom, and staff members Kevin and Diane Anderson. Guests present: Jerry Bergman, Wayne Frair (emeritus BOD), and George Howe (emeritus BOD). Unable to attend: Lane Lester, John Reed, and David Rodabaugh.

Devotions and prayer were led by Wayne Frair. Wayne's message outlined some trends in evolution. He encouraged us to hold up high standards in research. Wayne noted that at least 500 verses deal with creation; we're on the right track if we start with Biblical authority.

The Internet committee report by chairman Gary Locklair delved into two major areas: CRSnet and the creationresearch.org Web site. The CRSnet listserv continues to be a valuable asset to our members. There are nearly 260 participants on the list. Recently a survey of CRSnet users resulted in 27 responses – the overwhelming majority of responses were positive regarding the CRSnet. Members especially appreciated BOD participants on CRSnet. The CRS Web site, at creationresearch.org, continues to grow and gain exposure. Traffic at the site increased 46% over the previous year. Online sales, however, decreased 10% over the previous year. The members-only area of the Web site now numbers over 600. A number of items to improve member Internet services were discussed by the committee. The committee commended the volunteer work of Fred Williams as webmaster. The Internet committee encouraged all members of the BOD to participate in CRSnet and assist with improving the Web site. The Internet committee submitted an expense budget of \$1,000 for 2008–2009.

Discussion about various venues for the next board meeting was held. The decision was made to hold the 2009 BOD meeting on 11, 12, and 13 June

in the Los Angeles area, hosted by Mark Armitage and George Howe.

Danny Faulkner presented information about a general CRS conference to be held on 10 and 11 July 2009 at the University of South Carolina, Lancaster. The conference will consist of a number of presentations (presentations will be 20 minutes long with Q&A following and limited to one presentation per presenter) and an invited speaker.

The publication committee report by chairman Mike Oard was presented. Three books are in the pipeline to be published: *Rock Solid Answers* (challenges to the Flood addressed) published by Master Books; *Evidences* (a “coffee table” Creation book) with many contributors; *Rocks Are Not Clocks*, a CRS technical monograph. After discussions with Tim Dudley and Laura Welsh, the committee felt Master Books would be a good distributor for CRS. The committee mentioned the need to reach younger audiences with less technical information, especially as worldviews are set by the sixth grade. The committee reported a profit on book sales, decided to continue the CRSQ CD, and discussed the planned CRS display at the AIG museum. The publication committee submitted an expense budget of \$47,600 for 2008–2009.

The membership committee report by chairman Glen Wolfrom was presented. The colorful 2007/08 Membership-Subscription Report was distributed. The worldwide total number of members and subscribers was 1,761 (1,574 US, 187 foreign). This is a net increase of 39 over the previous year and represents the largest total over the past 10 years. Additionally, the records indicate that subscriptions were held by 219 libraries (194 US, 25 foreign). While the number of voting members was stable at nearly 700, there was a substantial increase in the number of sustaining members. The new option of “paperless” membership has been well received, with 48 members choosing

to access our publications only via the Web site. The committee challenged each member of the BOD to personally recruit at least one new voting member in the upcoming year. The membership committee submitted an expense budget of \$13,850 for 2008–2009.

The periodicals committee report by chairman Gene Chaffin was presented.

Possible changes for online availability and changes for authors were discussed. The *CRSQ* editor, Kevin Anderson, is pleased with the direction of the quarterly. The editor is not a gatekeeper but ensures scientific rigor is met and is always open to suggestions. The *CRSQ* has a 50% rejection rate. Concern was expressed over the thinness of the *CRSQ* cover, which is necessary to hold down the cost of publication and mailing. The BOD had positive comments for the editorial comments that have appeared in the quarterly. A page cost for authors was discussed but rejected at this time. The periodicals committee submitted an expense budget of \$43,000 for 2008–2009.

A brief report on *Creation Matters* was received from the editor, Glen Wolfrom. Glen is seeking a new editor for *Creation Matters*. We are currently publishing Volume 13. Six issues (bi-monthly) are typically published each year. For Volume 12, three issues were presented with magazine-style covers, while the remainder retained the newsletter-style cover. A new feature, titled “Math Matters,” was introduced last year, which appeared for a sequence of three issues. “Speaking of Science” and “All by Design” are regular features that are appreciated by the readers.

The research committee report by chairman Gene Chaffin reported on continued research and plans for future research. The committee recommended that the funding for the Grimmea 2 study of structures in mosses be increased to \$1100, that the Pyrenoids 1 study of pyrenoids in lowly terrestrial plants be

increased to \$1100, and that the Blue Green algae project be increased to \$1100. Several other projects are in progress, and the committee is considering possible new projects including undergraduate research pilot projects at the electron microscope facility at the VACRC and a flood sedimentation and fossilization project. The research committee submitted an expense budget of \$30,000 for 2008–2009.



(above) Pictured from left to right: Dave Kaufmann, George Howe, and Ted Aufdemberge

Financial secretary Ted Aufdemberge reported on the fiscal status of CRS. The status of the CRS investment portfolio was reviewed. Due to a decline in the U.S. economy and the transfer of \$62,031.27 from the non-endowment funds to our bank account in Chino Valley, AZ, the value of our investments decreased by 13% since the last report. On the bright side, our investments earned \$35,281.89 during that same period. It was moved, seconded, and passed that \$15,000.00 dollars of earned income be transferred to the CRS bank account and that the remainder be re-invested. A gift of stock received at the VACRC two years ago was converted to cash and is being used as a “buffer” in the bank account. Ted was commended for his faithful stewardship of CRS financial assets! The finance committee submitted an expense budget of \$0 for 2008–2009.

Treasurer Gary Locklair presented

an expense budget of \$260,450 for the 2008–2009 fiscal year. This represents a balanced budget in regards to expected income. After discussion, the budget was approved unanimously.

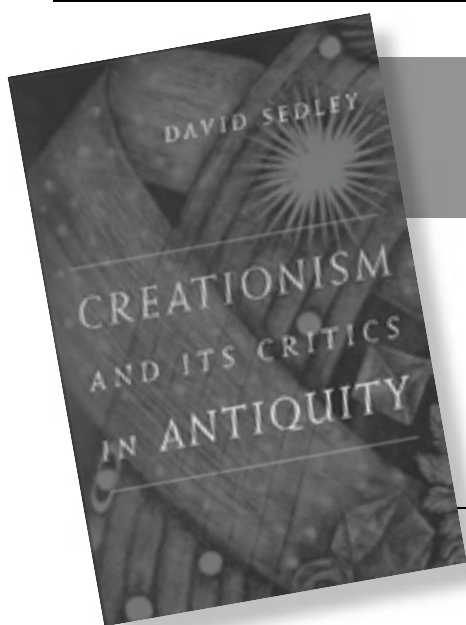
Three items of new business followed. The BOD expressed appreciation to AIG for their willingness to provide resources to CRS. An ad hoc committee was appointed for future dialog with AIG. Concerns and questions over the CRS archives and the archiving process were presented. After discussion, the previous proposal to move the CRS archives was rescinded by vote of the BOD and further action tabled for next year's meeting. The recording secretary will investigate a number of issues related to archiving. Changes to position descriptions were approved by vote of the BOD. The recording secretary will update the documentation accordingly.

Glen Wolfrom put forth the name of Jean Lightner as a possible candidate for the BOD. Her nomination was approved by vote of the BOD. In addition, the following current BOD members were nominated for reelection: Mark Armitage, Eugene Chaffin, John Reed, and Glen Wolfrom for the 2009 BOD election. These candidate names will be included on the 2009 ballot for membership consideration.

The following officers were elected for 2008–09: President, Don DeYoung; Vice President, Eugene Chaffin; Recording Secretary, Gary Locklair; Treasurer, Danny Faulkner; Financial Secretary, Mark Armitage; and Membership Secretary, Glen Wolfrom. The BOD thanked Dave Kaufmann and Ted Aufdemberge for their years of service on the executive committee as recording secretary and financial secretary respectively.

The meeting was adjourned at 1245 hours with the comment “BOD meetings are a pleasure to attend.”

Respectfully submitted,
Dr. Gary Locklair,
Recording Secretary



Book Review

Creationism and Its Critics in Antiquity

by David Sedley

University of California Press,
Berkeley, 2008, 296 pages,
\$30.00.

Author David Sedley is Laurence Professor of Ancient Philosophy at the University of Cambridge. This book is volume 66 of the Sather Classical Lectures given at the University of California, Berkeley. Lest we yawn at the thought of an erudite tome about ancient philosophers, we should first be gratified that classical thought is still taken seriously in some places, considering the modern sophistry that has taken its place.

Sedley traces the arguments for and against “creationism,” by which he means all views that explain the world’s structure and contents with reference to an intelligent designer. Thus he does not distinguish among what we would call young-earth creationism, intelligent design, or even theistic evolution.

The author focuses on Anaxagoras, Empedocles, Socrates, Plato, Aristotle, the atomists Democritus and Epicurus, the Stoics, and Galen. He shows how the major thinkers of antiquity developed their ideas on the world’s origins in a context of open-ended debate. How refreshing!

As Solomon said, there is nothing new under the sun. Variations of arguments used today were used in ancient times. For example, Sedley traces the first use of the argument from design to none other than Socrates. However,

since Socrates put piety ahead of theoretical knowledge, Sedley accuses him of being an “anti-scientific creationist.” But he acknowledges: “In the six centuries from Anaxagoras to Galen, creationism rarely took on an anti-scientific tenor” (p.242).

There is no ancient thinker who entirely anticipates modern theories of creation or evolution, for there is an admixture in everyone. For example, Empedocles envisions the formation of life in two phases, one ruled by love and the other by strife. The love phase is similar to creation, and the strife phase is like evolution. However, he and others like him seem closer to creationism since they describe original prototypes subsequently modified in the light of sin or deficiency.

The atomists clearly promoted naturalism and anticipated several evolutionary arguments such as the possibilities of deep time. They posited an infinite universe, and even infinitely many worlds, and argued that every possible atomic permutation was found somewhere. They combined this with a form of survival of the fittest and tried to account for purposive structures in nature via accident instead of design.

Plato followed Socrates in being mostly on the side of creationism but thought species arose out of one another, though he saw the process as one of

devolution, not evolution. Aristotle was more anticreationist than creationist. His emphasis on teleology would place him on the creationist side, but it was natural purpose, rather than intelligent purpose, that dominated. He also postulated an infinite world and a detached and self-absorbed God, which gave anticreationists much room for speculation.

“Stoicism,” Sedley says, “is in many ways best understood as an updated version of Socratic philosophy” (p.206), and the argument from design figures prominently in the Stoics writings. But they were fatalists and proposed the doctrine of an eternal recurrence, long forgotten until Nietzsche took it up. Galen was a creationist in Sedley’s sense who, like many classical thinkers, did not believe the Creator began *ex nihilo* but was a craftsman working with prior materials.

So in addition to the Judeo-Christian sources of creationism, there are lines of creationist thought from classical times. Since Western culture was built on a combination of Christian and classical culture, creationists would do well to show linkages with the classical arguments Sedley elucidates. It doesn’t hurt to have Socrates on our side.

Ralph Gillmann
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Instructions to Authors

Submission

Submit an original plus two copies of each manuscript to the editor of the *Creation Research Society Quarterly* (see the inside front cover for address). Concurrent submission of an electronic version (Word, WordPerfect, or Rich Text Format) of the manuscript text and graphics is also encouraged. The manuscript and graphics will not be returned to authors unless a stamped, self-addressed envelope accompanies submission. Manuscripts containing more than 30 pages are discouraged. An author who determines that the topic cannot be adequately covered within this number of pages is encouraged to submit separate papers that can be serialized.

All submitted manuscripts will be reviewed by two or more technical referees. However, each section editor of the *Quarterly* has final authority regarding the acceptance of a manuscript for publication. While some manuscripts may be accepted with little or no modification, typically editors will seek specific revisions of the manuscript before acceptance. Authors will then be asked to submit revisions based upon comments made by the referees. In these instances, authors are encouraged to submit a detailed letter explaining changes made in the revision, and, if necessary, give reasons for not incorporating specific changes suggested by the editor or reviewer. If an author believes the rejection of a manuscript was not justified, an appeal may be made to the *Quarterly* editor (details of appeal process at the Society's web site, www.creationresearch.org).

Authors who are unsure of proper English usage should have their manuscripts checked by someone proficient in the English language. Also, authors should endeavor to make certain the manuscript (particularly the references) conforms to the style and format of the *Quarterly*. Manuscripts may be rejected on the basis of poor English or lack of conformity to the proper format.

The *Quarterly* is a journal of original writings, and only under unusual circumstances will previously published material be reprinted. Questions regarding this should be submitted to the Editor (CRSQeditor@creationresearch.org) prior to submitting any previously published material. In addition, manuscripts submitted to the *Quarterly* should not be concurrently submitted to another journal. Violation of this will result in immediate rejection of the submitted manuscript. Also, if an author uses copyrighted photographs or other material, a release from the copyright holder should be submitted.

Appearance

Manuscripts shall be computer-printed or neatly typed. Lines should be double-spaced, including figure legends, table footnotes, and references. All pages should be sequentially numbered. Upon acceptance of the manuscript for publication, an electronic version is requested (Word, WordPerfect, or Rich Text Format), with the graphics in separate electronic files. However, if submission of an electronic final version is not possible for the author, then a cleanly printed or typed copy is acceptable.

Submitted manuscripts should have the following organizational format:

1. Title page. This page should contain the title of the manuscript, the author's name, and all relevant contact information (including mailing address, telephone number, fax number, and e-mail address). If the manuscript is submitted by multiple authors, one author should serve as the corresponding author, and this should be noted on the title page.

2. Abstract page. This is page 1 of the manuscript, and should contain the article title at the top, followed by the abstract for the article. Abstracts should be between 75 and 200 words in length and present an overview of the material discussed in the article, including all major conclusions. Use of abbreviations and references in the abstract should be avoided. This page should also contain at least five key words appropriate for identifying this article via a computer search.

3. Introduction. The introduction should provide sufficient background information to allow the reader to understand the relevance and significance of the article for creation science.

4. Body of the text. Two types of headings are typically used by the CRSQ. A major heading consists of a large font bold print that is centered in column, and is used for each major change of focus or topic. A minor heading consists of a regular font bold print that is flush to the left margin, and is used following a major heading and helps to organize points within each major topic. Do not split words with hyphens, or use all capital letters for any words. Also, do not use bold type, except for headings (italics can be occasionally used to draw distinction to specific words). Italics should not be used for foreign words in common usage, e.g., "et al.", "ibid.", "ca." and "ad infinitum." Previously published literature should be cited using the author's last name(s) and the year of publication (ex. Smith, 2003; Smith and Jones, 2003). If the citation has more than two authors, only the first author's name should appear (ex. Smith et al., 2003). Contributing authors should examine

this issue of the *CRSQ* or consult the Society's web site for specific examples as well as a more detailed explanation of manuscript preparation. Frequently-used terms can be abbreviated by placing abbreviations in parentheses following the first usage of the term in the text, for example, polyacrylamide gel electrophoresis (PAGE) or catastrophic plate tectonics (CPT). Only the abbreviation need be used afterward. If numerous abbreviations are used, authors should consider providing a list of abbreviations. Also, because of the variable usage of the terms "microevolution" and "macroevolution," authors should clearly define how they are specifically using these terms. Use of the term "creationism" should be avoided. All figures and tables should be cited in the body of the text, and be numbered in the sequential order that they appear in the text (figures and tables are numbered separately with Arabic and Roman numerals, respectively).

5. Summary. A summary paragraph(s) is often useful for readers. The summary should provide the reader an overview of the material just presented, and often helps the reader to summarize the salient points and conclusions the author has made throughout the text.

6. References. Authors should take extra measures to be certain that all references cited within the text are documented in the reference section. These references should be formatted in the current *CRSQ* style. (When the *Quarterly* appears in the references multiple times, then an abbreviation to *CRSQ* is acceptable.) The examples below cover the most common types of references:

Robinson, D.A., and D.P. Cavanaugh. 1998. A quantitative approach to baraminology with examples from the catarrhine primates. *CRSQ* 34:196–208.

Lipman, E.A., B. Schuler, O. Bakajin, and W.A. Eaton. 2003. Single-molecule measurement of protein folding kinetics. *Science* 301:1233–1235.

Margulis, L. 1971a. The origin of plant and animal cells. *American Scientific* 59:230–235.

———. 1971b. *Origin of Eukaryotic Cells*. Yale University Press, New Haven, CT.

Hitchcock, A.S. 1971. *Manual of Grasses of the United States*. Dover Publications, New York.

Walker, T.B. 1994. A Biblical geologic model. In Walsh, R.E. (editor), *Proceedings of the Third International Conference on Creationism* (technical symposium sessions), pp. 581–592. Creation Science Fellowship, Pittsburgh, PA.

7. Tables. All tables cited in the text should be individually placed in numerical order following the reference section, and not embedded in the text. Each table should have a header statement that serves as a title for that table (see a current issue of the *Quarterly* for specific examples). Use tabs, rather than multiple spaces, in aligning columns within a table. Tables should be composed with 14-point type to insure proper appearance in the columns of the *CRSQ*.

8. Figures. All figures cited in the text should be individually placed in numerical order, and placed after the tables. Do not embed figures in the text. Each figure should contain a legend that provides sufficient description to enable the reader to understand the basic concepts of the figure without needing to refer to the text. Legends should be on a separate page from the figure. All figures and drawings should be of high quality (hand-drawn illustrations and lettering should be professionally done). Images are to be a minimum resolution of 300 dpi at 100% size. Patterns, not shading, should be used to distinguish areas within graphs or other figures. Unacceptable illustrations will result in rejection of the manuscript. Authors are also strongly encouraged to submit an electronic version (.cdr, .cpt, .gif, .jpg, and .tif formats) of all figures in individual files that are separate from the electronic file containing the text and tables.

Special Sections

Letters to the Editor:

Submission of letters regarding topics relevant to the Society or creation science is encouraged. Submission of letters commenting upon articles published in the *Quarterly* will be published two issues after the article's original publication date. Authors will be given an opportunity for a concurrent response. No further letters referring to a specific *Quarterly* article will be published. Following this period, individuals who desire to write additional responses/comments (particularly critical comments) regarding a specific *Quarterly* article are encouraged to submit their own articles to the *Quarterly* for review and publication.

Editor's Forum:

Occasionally, the editor will invite individuals to submit differing opinions on specific topics relevant to the *Quarterly*. Each author will have opportunity to present a position paper (1500 words), and one response (750 words) to the differing position paper. In all matters, the editor will have final and complete editorial control. Topics for these forums will be solely at the editor's discretion, but suggestions of topics are welcome.

Book Reviews:

All book reviews should be submitted to the book review editor, who will determine the acceptability of each submitted review. Book reviews should be limited to 1000 words. Following the style of reviews printed in this issue, all book reviews should contain the following information: book title, author, publisher, publication date, number of pages, and retail cost. Reviews should endeavor to present the salient points of the book that are relevant to the issues of creation/evolution. Typically, such points are accompanied by the reviewer's analysis of the book's content, clarity, and relevance to the creation issue.

Creation Research Society

Membership/Subscription Application and Renewal Form

The membership/subscription categories are defined below:

1. **Voting Member** Those having at least an earned master's degree in a recognized area of science.
2. **Sustaining Member** Those without an advanced degree in science, but who are interested in and support the work of the Society.
3. **Student Member** Those who are enrolled full time in high schools, undergraduate colleges, or postgraduate science programs (e.g., MS, PhD, MD, and DVM). Those holding post-doctoral positions are not eligible. A graduate student with a MS degree may request voting member status while enrolled as a student member.
4. **Senior Member** Voting or sustaining members who are age 65 or older.
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6. **Subscriber** Libraries, churches, schools, etc., and individuals who do not subscribe to the Statement of Belief.

All members (categories 1–5 above) must subscribe to the Statement of Belief as defined on the next page.

Please complete the lower portion of this form and mail it with payment to CRS Membership Secretary, P.O. Box 8263, St. Joseph, MO 64508-8263, or fax for credit card payment to (816) 279-2312. Applications may also be completed online at creationresearch.org.



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† **New PAPERLESS option:** You may now opt out of receiving paper copies of the CRS periodicals (*CRS Quarterly* and *Creation Matters*). By choosing this option you may register for access to the Premium Area of the website, where you may view or download electronic (PDF) versions of these publications. Of course, regular members and subscribers may also have access to the Premium Area. Only members, however, will access to the Members Exclusive Area of the website.

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Creation Research Society

History—The Creation Research Society was organized in 1963, with Dr. Walter E. Lammerts as first president and editor of a quarterly publication. Initially started as an informal committee of 10 scientists, it has grown rapidly, evidently filling a need for an association devoted to research and publication in the field of scientific creation, with a current membership of over 600 voting members (graduate degrees in science) and about 1000 non-voting members. The *Creation Research Society Quarterly* has been gradually enlarged and improved and now is recognized as the outstanding publication in the field. In 1996 the CRSQ was joined by the newsletter *Creation Matters* as a source of information of interest to creationists.

Activities—The Society is a research and publication society, and also engages in various meetings and promotional activities. There is no affiliation with any other scientific or religious organizations. Its members conduct research on problems related to its purposes, and a research fund and research center are maintained to assist in such projects. Contributions to the research

fund for these purposes are tax deductible. As part of its vigorous research and field study programs, the Society operates The Van Andel Creation Research Center in Chino Valley, Arizona.

Membership—Voting membership is limited to scientists who have at least an earned graduate degree in a natural or applied science and subscribe to the Statement of Belief. Sustaining membership is available for those who do not meet the academic criterion for voting membership, but do subscribe to the Statement of Belief.

Statement of Belief—Members of the Creation Research Society, which include research scientists representing various fields of scientific inquiry, are committed to full belief in the Biblical record of creation and early history, and thus to a concept of dynamic special creation (as opposed to evolution) both of the universe and the earth with its complexity of living forms. We propose to re-evaluate science from this viewpoint, and since 1964 have published a quarterly of research articles in this field. *All members of the Society subscribe to the following statement of belief:*

1. The Bible is the written Word of God, and because it is inspired throughout, all its assertions are historically and scientifically true in all the original autographs. To the student of nature this means that the account of origins in Genesis is a factual presentation of simple historical truths.

2. All basic types of living things, including humans, were made by direct creative acts of God during the Creation Week described in Genesis. Whatever biological changes have occurred since Creation Week have accomplished only changes within the original created kinds.

3. The Great Flood described in Genesis, commonly referred to as the Noachian Flood, was a historical event worldwide in its extent and effect.

4. We are an organization of Christian men and women of science who accept Jesus Christ as our Lord and Savior. The act of the special creation of Adam and Eve as one man and woman and their subsequent fall into sin is the basis for our belief in the necessity of a Savior for all people. Therefore, salvation can come only through accepting Jesus Christ as our Savior.