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QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

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Biological Sciences

SCALED CHRYSOPHYTES FROM FLORIDA. VIII. OBSERVATIONS ON THE FLORA FROM THE SOUTHWEST

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Abstract: *A total of 33 silica-scaled chrysophytes (Chrysophyceae: 1* Paraphysomonas *sp. and 1* Spiniferomonas *sp.; Synurophyceae: 23* Mallomonas *spp. and 8* Synura *spp.) were recorded from 26 water bodies in seven south-west Florida counties using transmission electron microscopy. The number of taxa per location varied from zero to 11. Three new records for Florida were observed.*

Key Words: Chrysophyceae, silica-scaled chrysophytes, Synurophyceae

The work of Wujek and Siver and co-workers has revealed a diverse freshwater silica-scaled chrysophycean algal flora (Siver and Wujek, 1999 and literature therein; Wujek and Moghadam, 2001). For a general introduction to this taxonomic group, the reader is referred to the above citations. Chrysophytes in this paper are considered as scale-bearing Chrysophyceae and Synurophyceae (Andersen, 1987).

This study presents an account of the scale-bearing chrysophytes from the southwest part of Florida (seven counties, 26 samples) using scanning (SEM) and transmission electron microscopy (TEM). Correlates of these organisms, with ecological conditions present at the time of sampling, is discussed.

Materials and Methods—Plankton net (10 or 20μm mesh) collections were made over the period extending from January–March 2002 and 2003 from 26 locations in seven counties (Table 1). Preparations were as previously described (Wujek, 1984; Wujek and Bland, 1988, 1991) with TEM observations made using a Philips CM-10.

Physiochemical parameters taken in the field were: (1) surface water temperature, (2) pH (Hanna pocket pH meter), and (3) conductivity (Oakton WD-60), with each site specifically located using a global

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TABLE 1. South-west Florida plankton collection sites for silica-scaled chrysophytes, January to March, 2002 and 2003.

Sample No.	Location	GPS coordinates	pH	temp (°C)	conductivity µS/M	# taxa obs.
2002						
8 January						
De Soto County						
1	Peace River, at campground	27°13′40″N, 81°53′07″W	7.4	14.7	172	5
2	Pond, Peace River Camp Ground	27°13′46″N, 81°53′00″W	7.4	14.4	221	7
Sarasota County						
3	Ditch, FL Hwy 72, just 3 Km west of De Soto Co. line	27°11′33″N, 82°05′47″W	8.4	15.0	95.6	6
19 January						
4	Chestnut Creek Ponds corner Beckly Dr. & Venice East Dr. Circle	27°05′19″N, 82°22′52″W	8.2	22.0	755	5
8 February						
5	Cow Pen Slough Kings Gate Club	27°07′46″N, 82°25′36″W	8.3	20.0	505	5
6	Kings Gate Club Lake	27°08′57″N, 82°25′21″W	7.93	22.0	1145	3
12 February						
Charlotte County						
7	Ditch, Cook Brown Road	26°47′56″N, 81°46′04″W	7.5	20.0	123	3
Lee County						
8	Telegraph Creek on Hwy 78	26°43′56″N, 81°42′07″W	7.7	19.5	—	4
Hendry County						
9	Ditch, FL29, 6.5 km N of Sears Rd.	26°42′35″N, 81°26′18″W	7.5	20.0	123	6
Collier County						
10	Lake Trafford, Co. Park	26°26′00″N, 81°29′06″W	9.4	22.0	239	1
11	Roadside pond, Pepper Road	26°26′19″N, 81°29′17″W	7.6	23.0	213	3
Charlotte County						
12	Marl Lake 1, Babcock/ Webb WMA	26°51′28″N, 81°57′45″W	—	26.0	279	5
13	Marl Lake 2, Babcock/ Webb WMA	26°51′29″N, 81°57′49″W	—	23.0	351	2
14	Webb Lake, Babcock/ Webb WMA	26°51′26″N, 81°57′43″W	—	22.0	110	4

WMA = wildlife management area

TABLE 1. Continued.

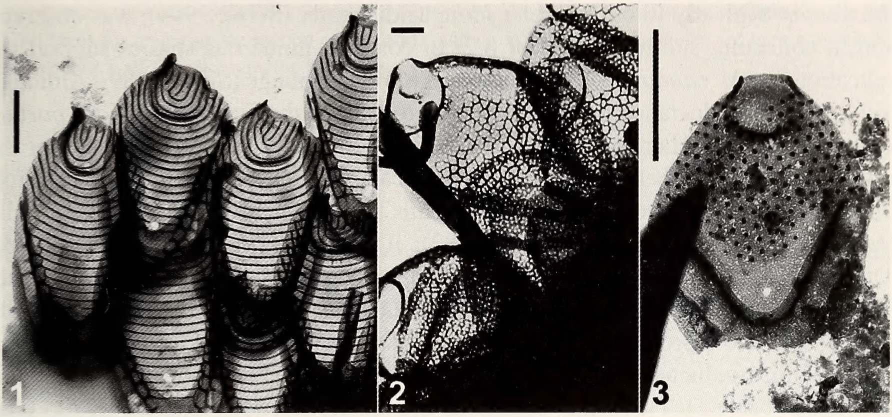
Sample No.	Location	GPS coordinates	pH	temp (°C)	conductivity μS/M	# taxa obs.
2003						
30 January						
Collier County						
18	Pond, east side Golf Club South	26°00′48″N, 81°37′19″W	6.72	16.0	651	1
19	Ditch on U.S. 41, 0.5km east of Port of the Islands Resort	25°57′36″N, 81°29′58″W	8.0	16.0	1042	3
20	H.P. Williams Wayside, U.S. 41	25°53′21″N, 81°41′50″W	7.7	17.0	418	6
21	Cypress marl wetland Dade Collier Training & Transition Airport Road	25°51′33″N, 80°55′29″W	7.85	25.0	365	8
Dade County						
22	Roadside ditch, U.S. 41	25°46′55″N, 80°50′56″W	7.5	17.0	436	11
Monroe County						
23	Ditch, Hwy 94	25°45′39″N, 80°53′59″W	7.25	18.0	406	3
24	Ditch, Hwy 94	25°44′56″N, 80°57′44″W	7.65	19.0	313	8
25	Roadside cypress pond	25°45′32″N, 81°03′13″W	7.15	20.0	413	9
11 March						
Sarasota County (all east of Nokomis)						
26	Weber Manufacturing pond 2430 Technology Dr., off Knights Trail	27°08′33″N, 82°24′24″W	6.85	27.0	360	4
27	Roadside ditch, corner Laurel Rd & Knights Trail	27°08′22″N, 82°24′04″W	7.9	26.0	301	3
28	Ditch, north side Laurel Road, immediately west of I-75	27°08′16″N, 82°24′59″W	8.0	27.0	1037	2
13 March						
29	Laurel Landing Estates pond along Kings Way Road	27°08′27″N, 82°25′47″W	7.05	24.0	860	0

positioning system (Magellan Trailblazer XL). Data analysis included the Pearson Correlation software on Minitab, Version 11.21 for Windows and SPSS, Version 10.0 for Windows, binary logistic regression as previously described (Wujek and Moghadam, 2001) to identify any relationship between the occurrence of a species and pH, conductivity, and/or temperature.

RESULTS AND DISCUSSION—A total of 33 taxa were observed (Table 2). Many of the species mentioned in previous papers were observed again. These are listed by name and location number (Table 2). Only those taxa not previously reported for Florida are illustrated (Figs. 1–3). The number of taxa observed from any one locality ranged from zero to 11 (Table 1).

TABLE 2. List of taxa observed in the south-west Florida collections. Taxa marked with an asterisk are new records for Florida. See Table 1 for locations. Where appropriate, stepwise logistic regression analysis for species showing the linear portion of the logistic regression equation for predicting presence/absence of each taxon based on physiochemical parameters is indicated (C = conductivity, T = temperature). Here: Prob(presence) = $1/(1 + e^{-Z})$, $Z = B_0 + B_1X_1 + B_2X_2 + \cdots + B_nX_n$.

Taxon	Location	p-value
Synurophyceae		
Mallomonas		
M. aerolata Nygaard	13	
M. akrokomos Ruttner	4	
M. asmundiae (Wujek & van der Veer) Nicholls	6	0.004 (C)
M caerula Siver	5	
M. caudata Ivanov em.	2, 5, 8, 9, 10, 12, 13, 25, 26, 27	
M. crassisquama (Asmund) Fott	4, 12, 13	
**M. cratis* Harris & Bradley	4	
M. cyathellata Wujek & Asmund	2, 4, 21	
M. guttata Wujek	22	
M. mangofera Harris & Bradley	26	0.017 (T)
M. mangofera Harris & Bradley f. *foveata* Dürrschmidt	11, 22	
M. matvienkoae var. *matvienkoae* (Matvienko) Asmund & Kristiansen	3, 11, 20, 21, 22, 26, 28	
M. multisetigera Dürrschmidt	5, 21, 24	
M. parvula Dürrschmidt	25, 27	
M. peronoides Momeu & Péterfi	7, 12	
M. pillula var. *pillula* Harris	4	
M. portae-ferreae Péterfi & Asmund	2, 18, 19, 22	0.002 (T)
**M. portae-ferreae* Péterfi & Asmund var. *reticulata* Gretz, Sommerfeld & Wujek	2, 20	
M. pseudocornata Prescott	13	
M. pseudocratis Dürrschmidt	9	
**M. rasilis* Dürrschmidt	22	
M. striata Asmund var. *serrata* Harris & Bradley	12, 14, 21, 22, 23, 24, 25	
M. tonsurata Teiling em. Krieger	26	0.017 (T)
Synura		
S. curtispina (Petersen & Hansen) Asmund	1, 2, 14, 20, 21, 22	
S. echinulata Korshikov f. *echinulata*	1, 3, 4, 7, 8, 9, 25	
S. mollispina (Petersen & Hansen) Péterfi & Momeu	2, 3, 7, 8, 9, 24, 25	0.049 (T)
S. petersenii Korshikov f. *petersenii*	1, 2, 3, 9, 19, 20, 21, 22, 23, 24, 25	0.001 (T)
S. petersenii f. *kufferathii* Petersen & Hansen	2, 5, 6	
S. spinosa Korshikov f. *spinosa*	1, 12, 14, 20, 21, 22, 23, 24, 25, 28	
S. spinosa Korshikov f. *longispina*	8	
S. uvella Ehrenberg em. Korshikov	1, 3, 20, 21, 22, 24, 25	0.046 (T)
Chrysophyceae		
Paraphysomonas		
P. vestita (Stokes) de Saedeleer	3, 4, 6, 9, 11, 14, 22, 25, 27	
Spiniferomonas		
S. trioralis Takahashi	22, 24	



FIGS. 1–3. Scale from *Mallomonas*. Fig. 1. *M. cratis*. Fig. 2. *M. portae-ferreae* var. *reticulata*. Fig. 3. *M. rasilis*. Scale bars = 1 μm.

Species richness was relatively large considering the elevated water temperatures observed in this study (Table 1). The most frequently observed *Synura* species were *S. petersenii* f. *petersenii* (present in 41% of the samples), *S. spinosa* (37%), and *S. echinulata*, *S. mollispina*, and *S. uvella* (26%). Frequently occurring taxa in other genera included *Mallomonas caudata* (37%), *M. matvienkoae* (26%), and *Paraphysomonas vestita* (33%). In contrast, 14 taxa were encountered at a single locality: *Mallomonas aerolata*, *M. akrokomos*, *M. asmundiae*, *M. caerula*, *M. cratis*, *M. guttata*, *M. mangofera*, *M. pillula* var. *pillula*, *M. pseudocoronata*, *M. pseudocratis*, *M. rasilis*, *M. tonsurata*, and *Synura spinosa* f. *longispina*.

Observed for the first time in the state were *M. cratis* (Fig. 1), *M. portae-ferreae* var. *reticulata* (Fig. 2), and *M. rasilis* (Fig. 3). All have been previously reported for the U.S. (see Kristiansen, 2002). Only observed for the second time in the U.S., with both of these reports from Florida, were *M. caerula*, originally described from the Ocala National Forest (Siver, 2002) and *M. pseudocratis* (Wujek and Moghadam, 2001), a species not widely distributed.

The water temperatures ranged from 13 to 27°C (Table 1). Despite its preference for cold water where it has often been observed under the ice in more northern regions (Cronberg and Kristiansen, 1980; Siver, 1991), cells of *M. akrokomos* were common in these elevated water temperatures. The presence of *M. caudata* at these higher temperatures is not surprising as it has a widespread seasonal distribution (Siver, 1991). Our observations of *M. pseudocoronata*, supports Siver's (1991) conclusion that it has a relatively high weighted mean temperature, 23°C in his study.

Species occurring within the widest temperature ranges observed, 22 to 29°C, were *Mallomonas caudata*, *Synura petersenii* f. *petersenii*, and *S. uvella*. The species occurring within the narrowest temperature range was *Mallomonas matvienkoae* var. *matvienkoae*, 23 to 26°C (Table 1).

The pH ranged from 6.7 to 9.4 with only four sites acidic (Table 1). Many of the species observed were in localities where the pH values were ≤8.0. *Mallomonas* *akrokomos*, typically found to prefer more acidic water (Siver, 1991), was observed from a collecting site with a pH of 8.2. In contrast, numerous studies support the indication that *M. caudata* is distributed over a wide pH range (Siver, 1989). Although both pH and conductance have been shown to control the occurrence of *M. portae-ferreae* (Siver and Hamer, 1989), our data showed no correlations with any of the physiochemical parameters (Table 2). Ecological data for *M. pseudocratis* are scarce. Ours is only the fifth world-wide report of this taxon, second for Florida. Originally described from Chile (Dürrschmidt, 1983), it has been reported from Sri Lanka (Dürrschmidt and Cronberg, 1989), India (Wujek and Saha, 1996), and most recently Florida (Wujek and Moghadam, 2001). Our study showed it occurred in waters with a pH of 7.5, and a preference for elevated specific conductances (Tables 1, 2).

Specific conductance ranged from 65.8 to 1145 μS/M with only eight less than 200 μS/M (Table 1). Two water bodies having the highest conductances (Kings Gate Club Lake-1145 μS/M and a ditch along U.S. 41-1042 μS/M) each had three chrysophyte species. Laurel Landing Estates pond, a site with the fourth highest specific conductance (860 μS/M), was the only site in which no scaled chrysophytes were observed. The largest ranges were observed in *Synura petersenii* f. *petersenii*, *Mallomonas caudata* and *Spiniferomonas trioralis*. The latter taxon was also reported as exhibiting a similar range in Alabama (Wujek and Menapace, 1998) and Texas (Wujek et al., 2002). In a Connecticut study, Siver and Hamer (1989) were the first to demonstrate the usefulness of specific conductivity in regulating the distribution of scaled chrysophytes. Siver (1993) later stated that "more studies, including their response to specific ions are needed before a conductivity gradient can be established" for these organisms.

Statistical analysis of the data was completed by running Pearson Correlations and Logistic Regressions to determine the existence and/or strength of the relationship between the presence/absence of a species at each site and the physiochemical factors at that site (Table 2). The accepted confidence level of the p-values for both the correlations and the regressions was 90%, indicated by p-values smaller than 0.05. The computed regression concordance value represents the percent certainty with which one could predict the presence/absence of a particular species based solely upon measurement of the physiochemical factors at a given site in the field.

Logistic regression analysis for nine taxa with physiochemical parameters was greatest with temperature (6 taxa), followed by specific conductance (1 taxon) with known taxa showing a relationship with pH (Table 2). While a significant relationship was found, low r^2 values indicated that relatively little variation in the presence/absence of a taxon could be explained by pH, specific conductance, and temperature. None of the three physiochemical parameters measured were correlated significantly with the number of taxa.

In conclusion, as has been demonstrated for other regions in Florida, the south-western region contains a diverse silica scaled chrysophyte flora. We believe further collections and observations from other Florida regions and other seasons will yield additional species. The silica scaled chrysophytes found in Florida based on electron microscopy now comprise 88 taxa.

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TERMITARIA CHARACTERISTICS OF *NASUTITERMES COSTALIS* IN A BELIZEAN RAINFOREST: IMPLICATIONS FOR LAND MANAGERS IN SOUTHERN FLORIDA

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Abstract: *We collected data on the location of termitaria (nest-sites) of the tree termite species* Nasutitermes costalis *at the La Milpa Field Station in northern Belize.* N. costalis *are ecologically relevant in Central America as decomposers in forest ecosystems and recently (late 1990s) have become an economic concern to land managers in southern Florida as an invasive pest species. Nests were non-uniformly distributed around nest-trees (Rayleigh's Test; $Z = 4.69$; $0.01 < P > 0.005$). Mean angle of termitaria placement was 10° (approximately north-northeast). 40% ($n = 30$) of the nests we measured were found at the base of the nest tree with all others located <1 m from the forest floor. We conclude that* N. costalis *prefer to place termitaria on the shaded, northern side of trees instead of the sun-exposed, southern side, presumably for water conservation and/or thermoregulation. Previous research has documented other adaptations for water conservation and thermoregulation in termites; however, we are aware of no other study that documents a preference for northern aspects in nest trees. We believe that entomologists and pest control specialists in Florida may find these results useful for locating, monitoring, and eradicating this invasive pest species.*

Key Words: Tree termite, termitaria, *Nasutitermes costalis*, invasive

Nasutitermes costalis, an ant-like tree termite species native to the Caribbean, is the first member of the genus *Nasutitermes* to be found outside of the tropics (Scheffrahn et al., 2002). Their native range extends across the tropics including Puerto Rica, St. Croix, St Lucia, and as far south as Venezuela. *N. costalis* were initially discovered in the USA by pest control professionals in May 2001 in Dania Beach, Broward County, Florida (Scheffrahn et al., 2002). *N. costalis* build free-standing termitaria on the ground or in trees, with foraging tubes that radiate from the nests to feeding sites (including trees, buildings, or other wood structures). *N. costalis* can cause significant damage in aboveground structures, as termitaria are quickly developed and upon establishment, termites produce deep foraging tubes into host trees. Although ecologically relevant in the tropics as decomposers (Lee and Wood, 1971; Bignell and Eggleton, 2000), land managers in Florida have developed control and monitoring initiatives, primarily via treatment of infested areas with liquid termiticide and/or gas fumigant (Thoms and Scheffrahn, 2001; 2002), to eradicate this invasive pest species.

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On 23 April 2003, the Florida Department of Agriculture and Consumer Services, pest-control officials, and entomologists from the University of Florida (led by Dr. Rudi Scheffrahn) initiated efforts to eradicate *N. costalis* within a 50-acre site in Dania Beach that is the only known area in the U.S. to host this invasive tree termite. Since the initial treatment in April of 2003, subsequent surveys and treatments of insecticide have been conducted at this site as efforts continue to eliminate *N. costalis* from southern Florida. According to Rudi Scheffrahn (2004), efforts to eradicate *N. costalis*, to date, have been quite successful. However, continued monitoring for nests and individuals of this species is planned to ensure that no individuals disperse and nest in new sites or in previously treated areas (Rudi Scheffrahn, 2004).

In this study, we present nest-site selection data for *N. costalis* in a part of their native range, within the Rio Bravo Conservation and Management Area (RBCMA) in northern Belize, C.A. Specifically, we measured nest-site orientation and height in host trees to determine if *N. costalis* termitaria were randomly or non-randomly placed on trees. We are aware of no other studies that document nest-site preferences or selection in any tree termite species. Although basketball-sized *N. costalis* termitaria are relatively easy to locate, such data may be useful to pest control officials and entomologists to selectively search and treat suspected areas for *N. costalis* termitaria, especially when nests are being built shortly after dispersal (a time when termitaria are small and difficult to locate; Rudi Scheffrahn, 2004).

STUDY SITE—All data were collected at the La Milpa Field Station in the RBCMA in north-western Belize, Orange Walk District, Central America. At approximately 101,175 ha (250,000 acres) the RBCMA is the largest private reserve in Belize and protects extensive areas of various habitats. The La Milpa Field Station is situated deep in the forests of the RBCMA, surrounded by nine hiking trails that penetrate into several different tropical forest types. The principal topographical features in this area are a series of escarpments aligned southwest-northeast, which also guide the drainage of the Rio Bravo, Booth's River, and New River systems. The area is subject to a 3-month dry season between February and April and a 2-peaked wet season with highest rainfall in June and October. Annual rainfall is approximately 1.55–1.60 m (61–63 inches) per year. The coolest period is from November to January, with an average temperature range from 21–26.5° C (69.8–79.1° F). The warmest period is April–May, when average maximum temperatures rise to 31.5° C (88.7° F).

Nest searches and data collection were conducted 20 May to 27 May 2003 (during the late dry season/early wet season) in semi-deciduous tropical broadleaf hardwood or cohune palm forest sites. Common trees in these forests included: cohune palm (*Attalea cohune*), chicle (or sapodilla; *Manilkara zapota*), provision tree (*Pachira aquatic*), *Cecropia* spp., bullhorn acacia (*Acacia sphaerocephala*), give-and-take palm (*Chrysophila argentea*), and *Ficus* spp.

METHODS—Transect surveys for *Nasutitermes costalis* termitaria were conducted on pre-existing trails within forests adjacent to the La Milpa Field Station (*see* Study Site for description). We identified the first 30 *N. costalis* termitaria encountered within a 20 m strip along our transects (10 m on each side of the transect [trail]). Once located, identification of *N. costalis* termitaria were verified with the assistance of local guides (Ramón Pacheco and Bladimere Rodriquez, Programme for Belize) using nest-site structure and termite morphology. At each nest-site, we collected nest aspect (using the nest tree as a center point) and nest height (from base). Aspect data were analyzed using a Rayleigh's Z Test (to test the null hypothesis that nests were uniformly distributed around the nest tree; Zar, 1999). Mean angle of nests on trees was calculated as described by Zar (1999). Nest height data were not analyzed statistically.

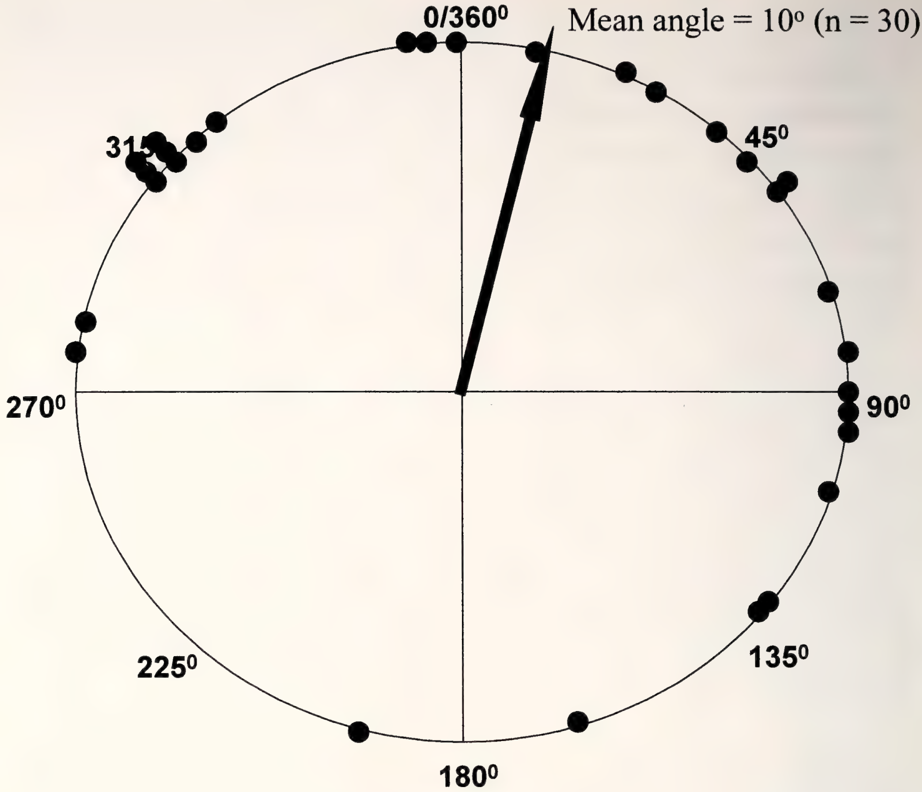

FIG. 1. Distribution (and mean angle) of *Nasutitermes costalis* termitaria aspect data.

RESULTS—*Nasutitermes costalis* termitaria were non-uniformly distributed around nest-trees ($Z = 4.69$; $0.01 < P > .005$). The mean angle of termitaria was 10° (approximately north-northeast; Figure 1). 40% (12 out of 30) of the nests were found at the base of the nest tree, with all others located <1 m from the forest floor.

DISCUSSION—*Nasutitermes costalis* preferentially place termitaria on the shaded and cooler, northern side of trees instead of the sun-exposed and hotter, southern side, presumably for water conservation and/or thermoregulation. All of the *N. costalis* nests observed in this study occurred in multi-layered, yet semi-deciduous tropical forests. At the time of our study (end of the dry season), many trees have shed their leaves, allowing sunlight to penetrate to the forest understory and floor. Thus, by constructing termitaria on the shaded, northern-side of trees, *N. costalis* may be selecting microhabitats that are damper and several degrees cooler than on other parts of a tree.

Water conservation and thermoregulation are two important life history constraints that regulate the distribution and activity of termite species (Howse, 1970; Wilson, 1971; Korb and Linsenmair, 1999). Previous research has documented thermoregulatory adaptations of termites associated with termitaria construction in tropical ecosystems (e.g., Howse, 1970; Wilson, 1971; Korb and Linsenmair, 1999). Furthermore, *N. costalis* time their emergence and dispersal from termitaria to coincide with the onset of the wet season in tropical ecosystems (Rudi Scheffrahn, 2004). We are not aware, however, of another study that documents nest-site preference for northern aspects in any other tree termite species.

Our results may be of interest to pest control officials in southern Florida, as well as entomologists in general. Land managers, pest control officials, and entomologists may find our results useful in locating, monitoring, and eradicating this invasive pest species. Land managers may be able to use our results to selectively search and treat infected areas. Our results also add to the body of knowledge of termite general ecology, as we are aware of no other study that documents preferences for termitaria placement in nest-trees among tree termite species.

Acknowledgments—This research was conducted during an international field course, Tropical Ecology of Belize, offered jointly through Ball State University, Muncie, IN, and Delaware County Community College, Media, PA, during summer 2003 (22 May–4 June). Thomas E. Morrell (along with S.M.A.) served as a co-instructor for this course. We thank Programme for Belize, our host agency in Belize, and our forest guides, Ramón Pacheco and Bladimere Rodriquez, who assisted in identification of *N. costalis* nests in the field. We are grateful to Rudi Scheffrahn (University of Florida) for providing insights regarding the biology and status of *N. costalis* in southern Florida.

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CHEMISTRY AT THE UNIVERSITY OF SOUTH FLORIDA (USF), 1960–2004

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Abstract: *Chemistry at USF is about 45 years old, and a number of changes have occurred in that time. The faculty has grown from four to over 30. Department status was obtained 40 years ago. The total amount available for research has grown from a few thousand dollars to over three million. The Department is now part of a research I university. The attitude toward research has obviously changed with the development of first a masters, then a doctoral program in chemistry. The tendency toward interdisciplinary research has been strong for many years. The balance between undergraduate and graduate is good. We can look with pride on the accomplishments of the faculty, staff, and alumni of 45 years.*

Key Words: anniversary, development, faculty, growth, program, research

Autumn 2004 was the 40th anniversary of department status for the Department of Chemistry at the University of South Florida (USF). (Prior to the autumn of 1964, it was a Program in Chemistry.) Now, USF has campuses in Tampa (central administration, home of the Medical Center, the H. Lee Moffitt Cancer Center and Research Institute, and the bulk of academic programs), St. Petersburg (home of the College of Marine Science), Sarasota-Manatee, and Lakeland. The Autumn-2004 head count was over 42,000 students, and there were about 100 baccalaureate, 80 masters programs, and over 35 doctoral programs. By the 68th commencement in December 2003, more than 175,000 students had been graduated, and there were more than 300,000 alumni.

The Department has grown as well. As of the fall, 2004 semester, the Department of Chemistry had 26 tenure-track faculty members, ten adjunct faculty members, 12 staff members, and 125 graduate students, and, recently, it had ranked as high as seventh in the nation in the number of chemistry majors produced. Over 65 tenure track faculty have served in the USF Department of Chemistry (Appendix 1).

Early days—When it was founded by the Florida legislature in 1956, USF had no name, no campus, no students, and no chemists. Land for the campus was donated in December 6, 1956: 1734 acres of scrub pasture covered mostly with a fine-grained quartz sand of low mineral content, representing what was described as "the second-worst soil" in Florida, about eight airline miles northeast of downtown Tampa (Cooper and Fisher, 1982).

Much was accomplished in 1957. Dr. John S. Allen, Vice President of the University of Florida was named the first President (January 27) (Cooper and Fisher, 1982; Anon, 2002a), the future university was named (October 22), Mr. Elliott Hardaway was lured away from the comfort of University of Florida to be the first librarian and the first professional-level person hired by Dr. Allen (Anon., 2002a). The decision to make all buildings air-conditioned was mandated (September 29), which made it possible for students to attend classes year round.

In time faculty were hired. The first faculty member, Dr. James D. Ray, Jr., a biologist (later Dean of the College of Natural Sciences) reported August 1, 1959 (Gristi, 1981). On September 1, 1960 some 134 charter faculty members reported, including four chemists (Appendix 1): Dr. Theodore Askounes Ashford from St. Louis University (Professor and Division of Natural Sciences Director), Dr. Laurence Monley from East Tennessee State (Associate Professor), Dr. Jack E. Fernandez from Tennessee Eastman Company (Assistant Professor), and Dr. T. W. Graham Solomons from a post-doctoral position with Professor Boekelheide at the University of Rochester (Instructor). The university officially opened on September 26 with 1,993 students in the charter class when Gov. LeRoy Collins spoke to an assembled group of about 6,000 (Cooper and Fisher, 1982.) When the ceremonies were over, the students went to their classes and everything was reportedly ready and on time, except that no faculty member could find chalk for the chalkboards, and chemists had to borrow test tubes from a nearby high school (Cooper and Fisher, 1982).

There were a limited number of buildings, three at the start—Administration, the University Center (UC), and Chemistry; two more—the Library and Fine Arts—were available by the end of the academic year. The women's dorm was the top floor of the UC. Because of a severe frost in 1959, state revenue was reduced, and the planned-for Library opened a year late. In 2003, USF had about 250 buildings (Anon., 2003). Chemistry was the original classroom building (78,000 gross square feet), three stories, with two auditoria (180, 200 seats respectively), laboratories (both teaching and research), classrooms, and offices (Anon, 2003). Why chemistry first? Dr. Allen told me in 1964 that it was because you could teach biology in a chemistry building, but you couldn't teach chemistry in a biology building.

Unique features—There were a number of unique features in the new university. Proximity was one; disciplines were close to each other. A colleague said you could get a broad education just walking down the hallway that connected the offices (Rothman, 2003). When I joined the faculty in 1964, I valued the exposure to faculty in education and geology, and would later collaborate with faculty in both. The proximity of other disciplines led to interdisciplinary research, less common at the time than now when it is highly encouraged.

Procedural adjustments had to be made because of the newness; procedures had to be developed, and adjustments made. For example, the Department of Audio-Visual Aids had responsibility for visual aids, which included more than one might expect. They would deliver a slide projector to your classroom when requested in advance. Geography faculty quickly learned that A-V also had the maps and expected to have them returned each night. Chemists had to teach A-V personnel that the periodic charts were expected to be left on the classroom walls (Solomons, 1964).

Academic challenges—Though 1,993 students were in the Charter Class in September 1960, only about 1,000 remained by the end of the academic year. The Chemistry Program had some good students, who would later go on to first-rate graduate schools and/or win awards for their achievements. Two chemistry majors (Carole Bennett and Jeanne Dyer) who were graduated in December 1963 became honored teachers of high school chemistry and won local, state, and national recognition. Joanna Fowler (B.A.'64) worked closely with Dr. Fernandez from the time that she was in general chemistry, and the work led to a publication (Fernandez et al., 1965). Dr. Fowler was elected to membership in the National Academy of Sciences in May, 2003.

Faculty members were encouraged to develop creative courses and programs. One such course was a general chemistry laboratory that covered the gas laws using vacuum lines, one for each pair of students. There were 12 units per room in the double laboratory that accommodated 48 students. Dr. Cal Maybury initiated the project in 1963, inspired by a program at his alma mater, The Johns Hopkins University. The system initially required some attention on his part because of the absence of a glass blower, but things improved in 1964 with the hiring of a glassblower (who helped Dr. Jesse Binford develop a physical chemistry lab project in which students fabricated their own glass electrodes for pH and other measurements). The system was creative and appropriately challenged students. The vacuum lines were finally dismantled when the general chemistry and other teaching laboratories were renovated in Dr. Owen's term as Chairman (1974–78).

A reported first-semester teaching load (Fall semester, 1960) included two sections of general chemistry, a two-hour laboratory section, and two sections of physical chemistry for a total of 14 contact hours (Rothman, 2002) . A charter faculty member commented, "The emphasis was on teaching not research. The feeling was that if you had time for research maybe you're not teaching enough" (Rothman, 2002).

By comparison, H. C. Brown noted that the typical teaching load at Wayne State University when he went there in 1943 was 18 hours a week, but he was promised 12 hours a week to be able to do some research (and the investment surely paid off) (Hargittai, 2000).

Books—Faculty were encouraged to write, though perhaps not in the early years, but certainly more so than might be expected for a department in an older, more established university. A number of monographs and textbooks were published (Appendix 2). The most successful, surely, is Solomons' *Organic Chemistry*, which is now in the eighth edition.

Expansion—The 44 years of existence have been years of growth and expansion. President Allen described the campus as the "place where the concrete never sets." Since the first groundbreaking in 1958, there has never been a day when something wasn't in some stage of construction on campus.

Expansion also occurred in the Chemistry Program (Appendix 1), as an effort was made to add two faculty members per year. 1962 was an exception and because of budget constraints, the Chemistry Program was able to add only one faculty member.

Research activities—The USF motto of the time was "Accent on Learning." And it applied to chemists in a significant way (Rothman, 2002). The official mindset did not favor research until about the third year of operation (Rothman, 2002). But the chemists persevered; they worked closely with their students, taught them well in the classroom, and worked with them in the small research labs. It could not have been an easy task, given the teaching loads, budget constraints, and limitations on equipment. Because of its young age, the Program lacked equipment that older institutions had.

Research programs need money. And research proposals were written early on. In May 1961, T. W. Graham Solomons, a Charter Faculty member (Appendix 1) was awarded USF's first research grant—$2,750 to study the synthesis and properties of a select group of organic molecules—and in November (1961), Jesse Binford was awarded a grant for $2,400 from the American Chemical Society (USF Research Office, 1995). In time, the program of working with undergraduate students in laboratories would be supported by NSF Undergraduate Research Participation Grants, with Jack E. Fernandez as the Principal Investigator. The Chemistry program progressed well, despite comparatively limited budgets and resources. Dedicated faculty were added (See Appendix 1). And they were willing to make sacrifices to achieve worthy goals. One was an A-60 NMR instrument, which ate up two years of budget (prior to 1964–65), but was regarded as a good investment. In recent years, the investment in NMR and X-ray equipment exceeded $1.5 million, and there was a considerable investment in equipment that would be useful to those interested in biochemistry and natural products.

The tendency to support research in a manner typical of a university increased over the years. The first two postdoctoral research associates, Edward J. Olszewski and K. Ramaiah arrived in the fall of 1964 and remained for a year. Significant senior faculty members were added at the full professor level (Appendix 1), and the development of the graduate programs made a significant difference. By 2004, the external grant/contract funding for the department was over $3 million and over 1000 papers had been published by USF chemistry faculty in scholarly publications (1969–1998; Martin, 2003).

Adding faculty who were interested in developing a major, well-funded research program came at a price called "start-up funds", which could vary at established universities from $500,000–$1 million, depending on the area of research and the extent to which the person depended on specialized instrumentation. Not surprisingly, college and central administrations question the magnitude of costs versus the payoff for proposed faculty members in chemistry.

In November 2003, Dr. Mike Zaworotko (Professor and Chairman), described a study of the impact of start-up funds given to department faculty members in recent years. The study (Zaworotko, 2004), looked at the costs associated with new faculty beginning with Dr. Kyung Jung (who came in 1996 and is now a tenured Associate Professor and Coordinator of the Division of Organic Chemistry) and included ten other faculty members who joined subsequently through Mohamed Eddaoudi (2002). The total start-up cost, provided entirely by the University, was $3.2 million. By comparison, Dr. Zaworotko found that the total value of grants and contracts raised by these faculty members had in 2003 already totaled \$7.9 million, and the amount of overhead that they generated was \$1.95 million.

Currently, department research seems to be focused on four interdisciplinary areas: drug design, material science, environmental chemistry, and chemical education. In 1965, faculty was organized into traditional divisions (analytical, inorganic, organic, physical, and later biochemistry), with some divisions a bit thin on faculty. Interdisciplinary collaborations were started before it was popular to do so in chemistry nationally possibly because of the assignment of chemists to buildings housing other disciplines. There has never been a building exclusively occupied by chemists, in contrast with the situation in more traditional departments. This was initially out of necessity, perhaps one that still continues on that basis. In autumn 1964, the first chemists moved out of the Chemistry Building (into the Physics Building), then in 1968, more chemists moved to the Science Center, then into the Bioscience Facility. We anticipate renovation of the Chemistry Building and completion of NES (Natural and Environmental Sciences) in 2005 that will lead to return of chemists to a renovated Chemistry Building and expansion into NES (which will be shared with Environmental Science & Policy and with Geography).

Start of the Graduate Programs, 1965—Between 1960 and 1973, the federal investment in higher education increased notably (\$732 million to \$5.8 billion), and this had implications on the organization and development of universities, including USF (Cooper and Fisher, 1982). Graduate programs were initiated in 1965 by the State Board of Control that supervised all state-supported universities in Florida.

Chemistry's preparations started in the 1964–65 academic year. The M.S. program was initiated in the Fall of 1965, and the Ph.D. program was initiated in the Fall of 1968. Various student applicants were screened and those selected appeared in the Fall of 1965. They included Robert F. Benson (deceased), Rosemary Oelrich Bettcher, Mike Holloway (deceased), Brad Johnson, Robert Peale, Jr., and Roger Walton. The selection process must have been good; all would receive master's degrees in what Conard Fernelius described as one of the tougher masters programs in the nation.

The justification for a doctoral program was that it would provide an opportunity for students working in industry to earn a degree when various commitments prevented them from going to the University of Florida or the Florida State University. In fact, most of the doctoral students were full-time students and this was a fairly persistent pattern through the years. Ours was one of the first doctoral programs; the very first in the natural sciences was one in Marine Biology.

There was a significant concern for quality of the Ph.D. program university-wide and for external creditability. Accordingly, from the outset, the final defense of the candidate's dissertation in addition to being a public defense was frequently a well-attended event, in contrast to the traditional absence of an audience at defenses at more established chemistry departments. In one instance, a chemistry dissertation defense was held in the Physics Building auditorium.

Another quality-control technique was use of an external examiner. The chairman of the defense committee is not the candidate's advisor, but a qualified person external to the department. Professor Bert Vallee (Harvard) served as external examiner for our first doctoral candidate (Anthony Girgenti, an advisee of Dr. Joseph Cory). Dr. Willard Libby, Nobel Laureate, served as an early Chair of the defense committee (1973) as did William P. Jenks, M.D. (for Dr. Young) and Dr. Esmond E. Snell (for Dr. Lopatin, the latter two students were advisees of Dr. Terence Owen).

The major products of an educational institution are creation of knowledge and its graduates. The sharing of knowledge through publications and books (Appendix 2) is important, as is the development of well-trained students. The "tracking project" is an effort to follow the careers of our graduate alumni and we have hopes of undertaking the same project with our undergraduate alumni as well (*http://www.cas.usf.edu/chemistry/new*). In looking at this list, we can recognize a millionaire entrepreneur, successful faculty members, successful industrial chemists, and other persons successful in other professions in whom we can take pride.

Ahead—Obviously, one would expect considerable change in a 40-year period, but the changes described here seem exceptional in number and extent. A significant number of faculty were lost to retirement in recent years (four in 2002–2003), but they have been slowly replaced. USF became a Research I university in the late 1990s, and this has had a significant impact on the expectation of all chemistry faculty, but especially newer ones. The demand for appropriate funding of research programs leads to a considerable emphasis on writing proposals and papers over books. Some younger faculty claim they spend 70% of their time on one aspect of proposals or another–either writing them or managing them. In addition, there is a considerable effort to balance the need for teaching large numbers of students to generate Student Credit Hours (SCH), and this may well be achieved by the device of bipartite faculty, one group of research-oriented professors who teach a limited number of students and a teaching–oriented faculty, whose efforts are exclusively focused on teaching. To this end, the department hopes to add five new faculty members by summer, 2005. At the same time, USF central administration is encouraging a greater involvement of undergraduate students in research projects with faculty members The worthiness of this new mandate is manifest; the ultimate outcome and balance with a graduate program is less evident.

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APPENDIX 1. Faculty Members of the USF Chemistry Department.

Name	Dates
Theo. Askounes Ashford	1960–81
Jack E. Fernandez	1960–95
Laurence E. Monley	1960–71 (85)
T. W. Graham Solomons	1960–90
Jesse S. Binford, Jr.	1961–03
P. Calvin Maybury	1961–87
Robert D. Whitaker	1962–92
Michael Barfield	1963–65
George Wenzinger	1963–99
Terence C. Owen	1964–98
Dean F. Martin	1964–
Eugene D. Olsen	1964–94
Jefferson C. Davis, Jr.	1965–98
George R. Jurch, Jr.	1966–98
Joseph G. Cory	1966–71
Robert S. Braman	1967–03
Brian Stevens	1967–99
Jay H. Worrell	1967–02
Winslow S. Caughey	1967–70
Ronald L. Birke	1969–74
W. Conard Fernelius	1970–75
Daniel L. Akins	1970–77
Larry G. Howell	1970–76
Douglas J. Raber	1970–91
Kin-Ping Wong	1970–75
Frank M. Dudley	1971–81
Stewart W. Schneller	1971–94

APPENDIX 1. Continued.

Name	Dates
William Swartz	1972–86
Janice O. Tsokos	1972–85
David L. Wilkinson	1972–76
Joseph A. Stanko	1973–03
Jon E. Wenzierl	1973–
Milton D. Johnston, Jr.	1973–
Paul D. Whitson	1975–79
David O. Lambeth	1973–77
Rebecca M. O'Malley	1977–
Sandor L. Vandor	1977–83
Gerald M. Carlson	1978–83
Jay Palmer	1978–80; 82–02
Steven H. Grossman	1981–
Raymond N. Castle	1981–94
Susan Jahoda	1981–84
Eric Wickstrom	1982–92
Leon Mandell	1984–00
Robert L. Potter	1984–
Towner B. Scheffler	1985–92
George R. Newkome	1986–01
Alfred T. D'Agostino	1987–94
Gerhard Meisels	1988–
Li-June Ming	1991–
Jan M. Robert	1992–99
Louis Carlacci	1993–00
Julie P. Harmon	1993–
Abdul Malik	1994–
Kyung Woon Jung	1996–
Edward Turos	1996–
Kirpal Bisht	1998–
Michael J. Zaworotko	1999–
David Merkler	1999–
Brian Space	2000–
Bill J. Baker	2001–
Jennifer Lewis	2001–
Randy Larsen	2002–
Mohamed Eddaoudi	2002–
Mark McLaughlin	2002–
Ellen Verdel	2003–
M. Acevedo-Duncan	2003–
Alfredo Cardenas	2003–
Rosa Walsh	2003–
Edwin Rivera	2004–

APPENDIX 2. Chemists who Served as Administrators.

Name	Position	Date
Laurence Monley	Program Chair	1960–63
P. Calvin Maybury	Chairman	1963–74
Terence C. Owen	Chairman	1974–78
Jefferson C. Davis, Jr.	Chairman	1978–82
		1995–98
William Swartz	Chairman	1982–86
Stewart W. Schneller	Chairman	1986–94
Jack E. Fernandez	Chairman	1994–95
Robert L. Potter	Interim Chair	1998–99
Michael J. Zaworotko	Chair	1999–
Other Administrators		
Theo A. Ashford	Division Director, Dean	1960–81
Leon Mandell	Dean	1984–90
George R. Newkome	V-P Research	1986–01
Gerald R. Meisels	Provost	1988–94
	Director, Coalition for Scientific Literacy	1994–

APPENDIX 3. Books Written By USF Department of Chemistry Faculty Members.

Theodore Askounes Ashford

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INFLUENCE OF ENVIRONMENTAL COMPLEXITY AND OVARIAN HORMONES ON PERFORMANCE OF THE SHORT-TAILED OPOSSUM *MONODELPHIS DOMESTICA* (DIDELPHIDAE) IN A RADIAL MAZE

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Abstract: *The purpose of this study was to assess the effects of ovarian hormones and environmental complexity on performance by females of the marsupial,* Monodelphis domestica *in an 8-arm radial maze. Subjects were ovariectomized (OV) or sham ovariectomized (SH) and housed either in complex (EC) or impoverished (IC) environments. Ten days after surgery, spatial working memory performance in the radial maze was assessed over a 20-day training period. Both SH and OV subjects exposed to EC conditions exhibited significantly higher mean number of correct arm choices in the first 8 visits as compared to IC subjects. Under EC conditions SH and OV subjects also achieved a higher mean number of correct choices before making an error. Food deprivation caused a disruption of the estrous cycle (a lengthening of 6-8 days); these disruptions occurred by the seventh day of maze training. During initial learning trials (before disruption of estrous), intact females exhibited a higher mean number of correct arm choices during the first 8 visits than did females from the OV group. Results indicated that although ovarian hormones and environmental complexity act independently and interactively to affect performance, environmental conditions exert a more pronounced influence on spatial learning than hormonal conditions. This is the first demonstration of these effects for a marsupial.*

Key Words: environmental complexity, *Monodelphis*, ovarian hormones, performance, radial maze

Numerous factors experienced by animals in early life, including hormone concentrations and environmental complexity, can have profound effects on brain chemistry (Punzo, 1996; McAllister et al., 1999), central nervous system development (Nilsson et al., 1999; Punzo and Ludwig, 2002; Punzo, 2004), and subsequent behaviors (Suomi, 1997; Buonomano and Merzenich, 1998). With respect to mammals, a common approach used to study effects of environmental complexity is to compare animals that have been reared under environmentally complex (EC) versus environmentally impoverished (IC) conditions (Rosenzweig and Bennett, 1996). Under EC conditions, young animals are allowed to interact with parents, siblings, and conspecifics, and they are typically housed in cages that contain a variety of objects to stimulate exploratory and locomotor activity such as tunnels, running wheels, and multi-colored blocks or platforms for climbing. In contrast, IC animals are typically reared in barren cages and in isolation from parents and conspecifics.

Mammals reared under EC conditions typically exhibit higher levels of catecholamine and steroid hormones (Oitzi and de Kloet, 1992), larger brains, increased levels of neurogenesis and synaptogenesis (Kempermann et al., 1997), and enhanced performance on locomotor activities (Punzo and Chavez, 2003), and tasks related to learning and memory (Wainwright et al., 1993; Nilsson et al., 1999). Most of this research has focused on placental mammals including rodents, felids, canids, suids, and primates (see reviews by Holson and Sackett, 1984; Rosenzweig and Bennett, 1996; Suomi, 1997). In contrast, few studies have addressed the general learning abilities of marsupials, This is interesting in view of the fact that marsupials are among the most ancient of mammals (Hunsaker, 1977). Furthermore, didelphids represent one of the most ancient marsupial families and have adapted to a wide variety of habitats (Stonehouse and Gilmore, 1977). Kimble and Whishaw (1994) showed that the short-tailed opossum (*Monodelphis domestica*) had the ability to learn working and reference memory components of a radial arm maze, but were unable to find a hidden platform when tested in a Morris water maze. *Monodelphis domestica* also has the ability to learn a complex maze with 6 blind alleys (Punzo and Farmer, 2004). Punzo and Pedrosa (2003) reported that protein malnutrition resulted in an impairment of visual discrimination learning in the sugar glider, *Petaurus breviceps.*

The short-tailed opossum, *Monodelphis doemstica* Gray (Didelphidae) is found in Bolivia, Paraguay and Brazil, where it resides in mesic rocky or thorn-scrub habitats (Vandeberg, 1983). They possess prehensile tails and are good climbers (Hunsaker, 1977). This nocturnal marsupial is omnivorous and typically feeds on a variety of arthropods, small rodents, snakes, and plant material (Storer, 1998). This species was imported into the United States (USA) in 1978 by the National Zoo in Washington, DC and has become popular in the pet trade industry worldwide. It has also been used in research on several aspects of marsupial physiology (Maitland and Ullmann, 1993) and sexual behavior (Trupin and Fadem, 1982).

To my knowledge, no data are available on the effects of environmental complexity and gonadal hormones on learning ability in marsupials. Research has shown that estrogen can exert effects on spatial learning and memory in rodents. For example, administration of exogenous estradiol improved working memory performance in rats tested in a radial maze (Luine and Rodriguez, 1994). Trupin and Fadem (1982) reported that systemic administration of estrogen significantly improved choice accuracy by ovariectomized rats in a T-maze. The purpose of this study was to assess the effect of ovarian hormones and environmental complexity on spatial learning by females of *M. domestica* in a radial maze.

METHODS—*Subjects*—Forty females of *M. domestica* were used in these experiments. Animals were 32 days of age, ranged in body weight from 123 to 126 g, and were third-generation offspring of captive bred adults that were originally collected from the Caatingia region of northwestern Brazil in 1997 and imported by Rainforest Inc., Tampa, Florida, USA. These animals were collected at sites separated by 9 to 23 km. Animal care followed guidelines set by the National Institutes of Health Guide for the Care and Use of Laboratory Animals. Opossums were housed in a temperature-controlled room (31 to 32^{O}C, 22 to 55% relative humidity) under a 14L:10D photoperiod regime, conditions described as optimal for breeding success and viability (Trupin and Fadem, 1982). At 32 days of age, 20 subjects were ovariectomized (OV group) and 20 received sham surgeries (SH group). Animals were anaesthetized by intraperitoneal injection using sodium pentabarbitol (0.6 mg/100 g body weight) as proscribed by Vanderberg (1983).

Environmental conditions—Animals were maintained under similar conditions before and after surgery as follows: 10 days after surgery, subjects under each hormonal condition were randomly assigned to either an environmentally impoverished (IC) or enriched (EC) environment. Housing conditions were maintained throughout the course of experiments. Subjects assigned to the IC group were housed individually in plastic rodent cages (40 × 40 × 30 cm; Bush Herpetological Supply, Neodesha, Kansas) containing a vermiculite substrate, and received minimal handling. Subjects in the EC group were housed in groups of 10 (5 females from each hormone condition) in plastic cages (125 × 65 × 35 cm) containing the same substrate material and a variety of novel objects for stimulation including multicolored wooden blocks (4 × 4 × 4 cm; 7/cage), running wheels (one/cage), wooden ladders (4/cage), and multicolored cylindrical tubes (15 cm in length, 8 cm in diameter; 3/cage). All subjects were provided with food and water ad libitum prior to food deprivation procedures. Animals were fed on a diet consisting of dry commercial cat chow (Purina Cat Chow, Ralston Purina, St. Louis, Missouri), supplimented every 3 days with fresh banana, apple slices, and rolled oats.

Procedure for assessing performance in a radial arm maze—Twenty-one days after exposure to the environmental conditions described above, all subjects were deprived of food until they achieved 90% of their pre-training body weight. Thereafter, no more than a 4-g per week weight gain was allowed. The effect of food deprivation on female estrous cycles was monitored daily via lavage of the urogenital sinus using saline-moistened cotton swabs (Trupin and Fadem, 1982). The estrous cycle for *M. domestica* maintained in the laboratory ranged from 27 to 28 days, with behavioral estrous lasting 34 to 36 hr. Lavages were examined daily throughout the experiments and were initiated 10 days prior to the onset of food deprivation. Maze training sessions began after 3 days of food deprivation.

Subjects were trained to obtain a food reward (Planters Honey Peanuts) located at the ends of each arm of a standard elevated 8-arm radial maze. The maze was obtained commercially from Columbia Instruments (Columbus, Ohio; Model 0500-2-D40). A detailed diagram and description of this maze can be found in Punzo and Farmer (2004). To summarize, the maze was constructed of white stainless steel, with an octagonal central arena 26.7 cm in diameter, and 8 arms, each 42 cm in length, 12.5 cm in width, and 10 cm in height. The entrance of each arm was provided with a guillotine door that could be opened or closed using a mechanical relay. A small hole in the floor at the end of each arm (2.5 cm in diameter, 1.5 cm deep) served as a food cup into which the food rewards (2 peanuts/food cup) were placed. The maze and animal housing cages were located in the same room which contained a variety of extramaze cues (windows, shelves, overhead lighting).

At the beginning of each trial an individual subject was placed in the central arena with the doors and arms closed. All doors were then opened and the subject was allowed to enter any arm. An arm choice was scored if the subject traveled one-third of the length of the arm. Subjects were allowed to choose arms in any order until all arms were visited or until 10 min had elapsed. An error was scored in 2 ways: (1) number of correct choices in the first 8 visits, and (2) number of correct choices until the first error. Each subject was tested once per day between 0900 and 1000 hr for 20 consecutive days. Data were expressed in 4-day blocks.

Statistical analyses—All statistical analyses followed procedures as outlined by Sokal and Rohlf (1995). A Bartlett's Test showed homogeneity of variances, and G Tests showed that error variances were normally distributed. Choice accuracy data collected over 20 days were analyzed using a three-way analysis of variance (ANOVA: hormone condition, environmental condition, 4-day blocks), with repeated measures on block.

RESULTS—Both gonadally intact (SH) and ovariectomized (OV) females exposed to complex (EC) environmental conditions exhibited a significantly higher mean number of correct arm choices in the first 8 visits: EC / SH: 6.63 ± 0.32 SE; EC / OV: 6.82 ± 0.29; IC / SH: 4.54 ± 0.37; IC / OV: 4.72 ± 0.29) ($F_{1, 136} = 35.44$, $P < 0.01$) as compared to SH and OV subjects exposed to IC conditions. In addition, SH and OV subjects exposed to EC conditions also achieved a higher mean

TABLE 1. Effects of environmental complexity and ovarian hormones on performance by females of *Monodelphis domestica* in a radial arm maze. Data represent mean (± SE) number of correct choices until first error, averaged over a 20-day training period. Ovariectomized and sham-operated subjects were housed under environmentally complex or impoverished conditions 10 days after surgery and throughout maze experiments. Data analysis showed a significant main effect of environmental condition; numbers followed by different letters: $P < 0.01$.

Experimental Group	Overall Mean (±SE)
Sham ovariectomy/complex environment	6.52a (0.52)
Ovariectomized/complex environment	6.37a (0.37)
Sham ovariectomy/impoverished environment	4.66b (0.31)
Ovariectomized/impoverished environment	4.62b (0.28)

number of correct choices before making an error ($F_{1, 136}=45.92, P < 0.01$) (Table 1). There was also a significant block effect for mean number of correct choices for the first 8 visits ($F_{4, 544} = 17.08$, $P < 0.01$) and for mean number correct before the first error ($F_{5, 680} = 18.24$, $P < 0.01$). These results indicate that the performance of all experimental groups improved over the training period (Table 2, A). There was also a significant environment x block interaction ($F_{4, 544} = 6.02$, $P < 0.03$), which suggests that the environmental effect differed across blocks. The data in Table 2B show that the effect of environment did not manifest itself until the second 4-day block of training.

Results from examinations of urogenital sinus lavage showed that gonadally-intact females all exhibited normal estrous cycles prior to initiation of food deprivation. In contrast, following food deprivation there was a disruption of the estrous cycle in all of the intact females, with an increase of 6 to 8 days. These alterations occurred by the seventh day of maze training. No significant effect of hormone or hormone × block interaction was observed. However, analyses of the effect of hormonal condition on maze performance during each 4-day block indicated that during the first block of trials (before the estrous cycle was disrupted) intact females exhibited a higher mean number of correct arm choices in the first 8 visits as compared to females from the OV group ($F_{1, 136} = 9.04$, $P < 0.04$) (Table 2, C), with no significant environment × hormone interaction.

DISCUSSION—These results show that environmental complexity and ovarian hormones can independently and interactively affect performance of *M. domestica* in a radial arm maze. This is the first demonstration of such effects for a marsupial, and is in agreement with similar findings reported for female rodents in radial (Korol et al., 1994; Daniel et al., 1999) and T-maze (Fader et al., 1998) experiments. In addition, gonadally-intact females performed better than ovariectomized females during the initial phase of maze learning before the disruptive effects of food deprivation were manifested.

These experiments indicate that ovarian hormones enhance performance of *M. domestica* females during the acquisition stage of a radial arm maze task. Furthermore, this improved performance occurred during the earlier phase of acquisition but did not persist over the 20-day training period.

TABLE 2. Effects of ovarian hormones and environmental complexity on performance by females of *Monodelphis domestica* in an 8-arm radial maze. Subjects were ovariectomized (OV) or sham ovariectomized (SH) and housed either under complex (EC) or impoverished (IC) environments. Data expressed as mean (± SE) number of correct choices for the first 8 visits represented in 4-day training blocks, over a 20-day training period. Within each group (A–C), numbers in columns followed by an asterisk are significantly different ($P < 0.01$).

Experimental Group	Number of correct choices for first 8 visits Four-day blocks				
	1	2	3	4	5
A. Effect of hormonal and environmental condition					
EC / SH	6.31 (0.21)	6.52 (0.32)	6.44 (0.52)	6.82 (0.42)	7.15 (0.53)
EC / OV	5.63 (0.35)	6.18 (0.53)	6.57 (0.34)	6.72 (0.61)	6.98 (0.39)
IC / SH	6.16 (0.51)	5.67 (0.35)	5.74 (0.43)	6.25 (0.50)	6.37 (0.45)
IC / OV	5.92 (0.28)	5.35 (0.46)	5.83 (0.34)	5.95 (0.54)	6.22 (0.24)
B. Effect of environment					
EC	5.93 (0.44)	6.33* (0.31)	6.76* (0.56)	6.84* (0.43)	7.14* (0.41)
IC	5.89 (0.32)	5.42 (0.41)	5.62 (0.32)	6.12 (0.51)	6.25 (0.51)
C. Effect of hormone					
SH	6.27* (0.21)	6.13 (0.42)	6.26 (0.32)	6.63 (0.35)	6.62 (0.44)
OV	5.41 (0.32)	5.92 (0.28)	6.32 (0.48)	6.62 (0.51)	6.65 (0.38)

These results are consistent with previous reports that ovarian hormones can influence spatial learning and memory processes in other mammals (Stackman et al. 1997; Warren and Juraska, 1997). This is not surprising in that estrogen and estradiol have been shown to alter the structural, neurochemical and electrophysiology of the hippocampus, a brain region associated with the mediation of spatial learning processes (Loy et al., 1988; Maggi et al., 1989). At the cellular level, hippocampal neurons grown in tissue culture can double the density of their dendritic spines following administration of exogenous estradiol (Woolley et al., 1990). Ovarian hormones can also affect cholinergic pathways in areas of the basal forebrain and hippocampus, and acetylcholine (Ach) has been implicated as a neurotransmitter that plays an important role in the regulation of learning and memory (Gibbs et al., 1997).

These results also show that females of *M. domestica* exposed to an environmentally complex condition also exhibit enhanced performance in a radial maze. The effects of EC conditions on CNS development, neuroanatomy, and neurochemistry in placental mammals are well known (see reviews by Mistretta and Bradley, 1978; Greenough and Sirevaag, 1991; Rosenzweig and Bennett, 1996). Animals reared under EC conditions typically exhibit an increase in: (1) cortical weight and thickness; (2) degree of dendritic branching of cortical neurons; (3) number of dendritic spines in neurons associated with the cerebral cortex, medial septum, nucleus magnocellularis, hippocampus, and basal forebrain; (4) immunoreactivity of basal forebrain neurons for acetylcholinesterase, an enzyme required for synthesis of Ach; and (5) brain concentrations of low molecular weight peptides, neurotransmitters, and neuromodulators. With respect to behavior, enriched environments are associated with enhanced performance on a variety of spatial and non-spatial learning tasks including maze learning (T-maze, Y-maze, complex mazes, and radial mazes), oddity learning, operant conditioning, and visual discrimination (Holson and Sackett, 1984; Rosenzweig and Bennett, 1996).

In conclusion, the results of these experiments indicate that ovarian hormones and environmental complexity can interact to improve performance on a spatial learning task by a marsupial, *M. domestica*. This finding suggests that the ability of neural substrates to respond differentially to hormonal and environmental changes occurred rather early in mammalian evolution. Finally, these results also suggest that environmental factors exert a more pronounced affect on spatial learning than do endocrinological factors.

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HURRICANE-INDUCED PROPAGATION AND RAPID REGROWTH OF THE WEEDY BROWN ALGA *DICTYOTA* IN THE FLORIDA KEYS

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Abstract: *Hurricanes drastically affect shallow coral reef ecosystems by physically removing and fragmenting biological organisms, or scouring them as massive amounts of sand and rubble are displaced. This study assesses the impact of a Category I hurricane on populations of the weedy brown macroalga* Dictyota *in the Florida Keys, and considers the fate of the algal biomass shredded and displaced by subsequent water flow. In October 1999, Hurricane Irene decimated* Dictyota *spp. populations, however fragments created remained viable despite their traumatic generation, settled and formed attachment rhizoids within 2 days, and then began to grow. This study shows that a large-scale physical disturbance (hurricane) can be beneficial to weedy, opportunistic, asexually reproducing species, such as* Dictyota, *that form rhizoidal attachments faster than other macroalgal species, and can lead to large-scale population recovery within weeks.*

Key Words: asexual reproduction, macroalgae, physical disturbance, vegetative fragmentation

Although the mechanical effects of hurricanes on tropical terrestrial and reef communities are well documented (Greenwood and Hatheway, 1996; Young and Burchell, 1996; Wang, 1997; Russo, 1998; Wilson et al., 1998; Xie et al., 1998; Herbert et al., 1999; Lugo et al., 2000), the stresses imposed on individual benthic organisms by catastrophic storms are less well known (Bythell et al., 2000; Ostrander et al., 2000). Many marine invertebrates fragment in response to disturbance and the fragments are able to produce new individuals (Wulff, 1991; Tsurumi and Reiswig,

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1997; Bruno, 1998; Smith and Hughes, 1999). However, the role of natural cycles in producing viable algal fragments in tropical reef environments and understanding the real-life recovery of algal assemblages after severe storms remains poorly characterized for most tropical to subtropical reef algae (Kilar and McLachlan, 1986; Walters and Smith, 1994; Smith and Walters, 1999; Walters et al., 2002). Further, the importance of fragmentation processes in selective dispersal of weedy algae has not been considered.

Fragmentation as a means of clonal reproduction is a well-known method of plant and animal species propagation (Ramus, 1971; Fralick and Mathieson, 1972; Kilar and McLachlan, 1986; Wulff, 1991; Rodriguez, 1996; Bruno, 1998; Ceccherelli and Cinelli, 1999; Smith and Walters, 1999). Weedy species, either native or introduced, have rapid rates of growth and short life-cycles, allowing them to quickly dominate and persist in a habitat. Weedy species that have evolved methods of clonal fragmentation of adult individuals bypass the cycle of sexual reproduction and can rapidly boost apparent population size by quickly colonizing vacant niches (Mack et al., 2000), even in areas of high community species richness.

Although many weedy species are native to the environments they inhabit, the ecological havoc caused by some accidentally introduced invasive weeds has often led researchers to assume that all population explosions of such species are indicative of deteriorating habitats, usually as the result of anthropogenic activities (Mack et al., 2000). For instance, in the marine environment many algal blooms are the result of invasive species introduced via shipping (Russell, 1992), aquaculture (Carlton and Scanlon, 1985; Bird et al., 1993; Garbary et al., 1997) or the aquarium trade (Meinesz and Hesse, 1991; Jousson et al., 1998). A current example of this is the rapid growth and population expansion of the marine green alga *Caulerpa taxifolia* in the Mediterranean (de Villèle and Verlaque, 1995; Bellan-Santini et al., 1996; Gacia et al., 1996; Ferrer et al., 1997; Ceccherelli and Cinelli, 1999; Vroom and Smith, 2001). However, blooms that involve native species rather than alien invasives may be natural, regular occurrences in terrestrial and marine systems where weedy species increase apparent population sizes as space is opened through events such as hurricanes.

In the Caribbean, increases in algal cover by native species have recently been documented (Williams and Polunin, 2001). A variety of culprits including dieback of the herbivorous sea urchin *Diadema antillarum* and increased nutrient regimes have been cited as possible causes for increases in algal population numbers (Hughes et al., 1987, 1999; Lapointe, 1997, 1999). Regardless of the factors that might promote an increase in algal population numbers, the mechanisms behind these apparent increases remain largely unexplored. For instance, are plants reproducing sexually or asexually at faster rates? Physical disturbances, such as hurricanes, may offer clues for one possible mechanism of population increases in certain species of tropical reef algae.

Hurricane Irene, a Category 1 hurricane with sustained winds of 113 km hr^{-1}, passed near Conch Reef in the Florida Keys on 15 October 1999 (for a NOAA summary of Hurricane Irene, see: http://www.aoml.noaa.gov/hrd/Storm_pages/irene1999). Access to two long-term research sites at Conch Reef within 48 hours of the storm provided an unprecedented opportunity to study the impact of a hurricane on mixed *Dictyota menstrualis* (Hoyt) Schnetter, Hörnig and Weber-Peukert and *D. pulchella* Hörnig and Schnetter (Phaeophyta) populations (Schneider and Searles, 1991; Littler and Littler, 1997; Hanisak and Overdorf, 1998) and the reef community as a whole. Both *Dictyota* species are weedy, free-living and epiphytic algae commonly found on Conch Reef, and throughout the Florida Keys. Both exhibit a dichotomously branching blade and have a one-celled meduallary layer, anatomical features that result in rapid growth and easily torn tissues. Under non-hurricane conditions, *Dictyota* spp. populations may be extremely dense (Williams and Polunin, 2001), forming blooms several centimeters in height over the substratum that easily dislodge to form drifting "tumbleweeds" (PV, personal observation).

This study was initiated immediately after Hurricane Irene swept past the Florida Keys. The purpose was to: 1) assess abundance of *Dictyota* spp. before, during, and after storm impact, 2) assess whether hurricanes significantly increase the number of viable fragments of *Dictyota* spp., 3) determine the length of time these fragments may remain in the water column, and 4) determine the proportion of fragments that can successfully reattach to the substrate after their traumatic generation.

MATERIALS AND METHODS—*Site description*—Conch Reef is a fringing reef dating back to the Holocene and is located 5 km off Islamorada in the Florida Keys National Marine Sanctuary. Two sites were studied either annually or biannually in 1994, and from 1997 through 2000. "Shallow Conch" (24°57′047″N 80°27′657″W), a back reef ranging in depth from 4 m to 7 m, is characterized by uniform topography. In contrast, "Pinnacle" (24°56′870″N 80°27′276″W), located ca. 700 m to the east, is a reef slope with a high level of vertical relief and depths from 15 to 22 m. Both sites were accessed by SCUBA divers.

Percent cover—The Random Point Contact (RPC) method (Littler and Littler, 1985) was used to determine percent cover of *Dictyota* spp. at both study sites. Forty random points at 10 randomly selected distances along 3 permanent 50 m transects (25 m apart) were sampled during each sampling period.

Fragment flux and fragment size—Ten, 0.25 m^2 quadrats were haphazardly established at each study site after Hurricane Irene made landfall on 15 October 1999 to assess the extent of *Dictyota* spp. fragmentation. Quadrats were visited daily for five consecutive days starting on 18 October, 1999 and on 25 October to determine fragment flux directly after the hurricane, and again for three consecutive days starting on 15 November, 1999 to determine fragment flux under non-hurricane conditions. On each day, the substratum within each quadrat was gently fanned by hand and all unattached algal fragments were collected, placed in 500 mL centrifuge tubes where one end had been replaced by nylon stocking mesh, and transported back to the laboratory in insulated coolers of ambient seawater where abundance and blotted dry weights were determined. Because fragments often consisted of little more than apical tips of branches, species determination was difficult, and fragments of both species of *Dictyota* were analyzed together.

Sinking rates, survival and attachment of fragments—Fragments collected from each quadrat were placed in 150 mL Solo™ clear plastic (PETE) drinking cups with one cm of sand and 100 mL seawater upon return to the laboratory. Fragments were monitored daily to determine viability (tissue necrosis), rhizoid production, and rhizoid attachment. Field-station conditions hampered precise sinking rate analyses (e.g. no thermal controls or vessels large enough to eliminate wall effects were used), however rough sinking rate estimates were determined by excising fragments of different sizes and weights (n = 45), placing the fragments into a 100 mL graduated cylinder (water height of 19 cm), and recording sinking time for each fragment (normalized for height of the static water column). These data are presented anecdotally.

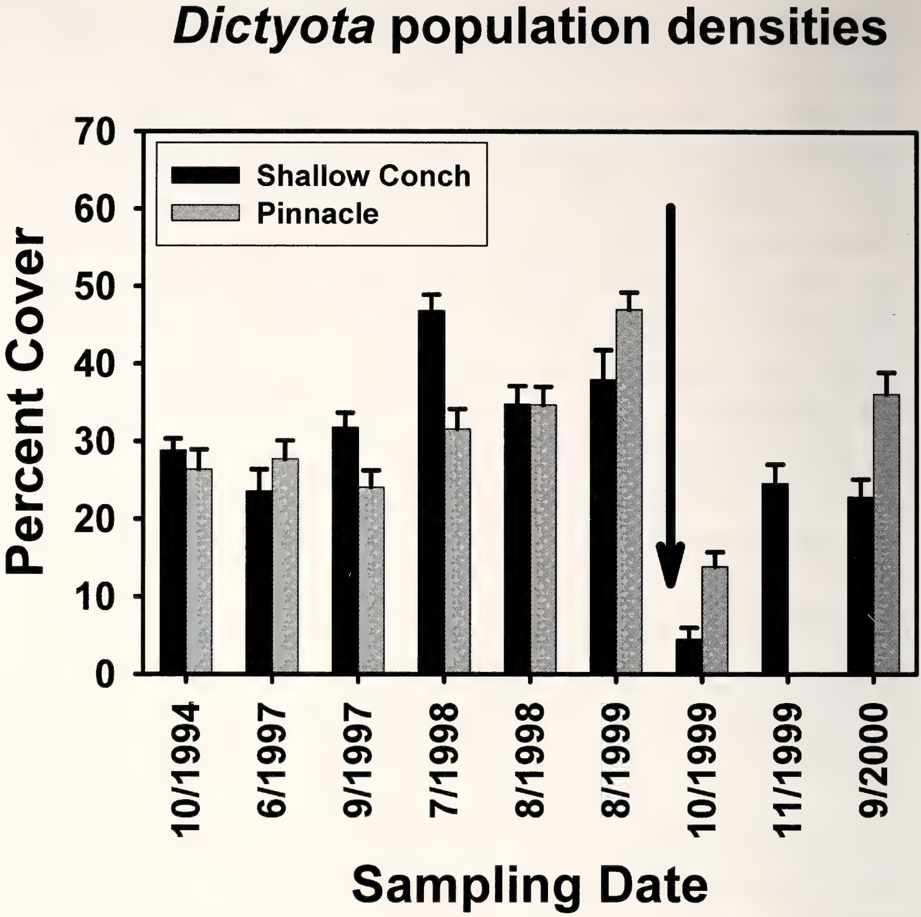

FIG. 1. Percent cover of *Dictyota* spp. at Conch Reef (mean ± SE) as determined by the Random Point Contact method. Mean percent cover of *Dictyota* spp. varied significantly over time ($p < 0.0001$). No significant differences of mean percent cover of *Dictyota* spp. existed between the 2 sites ($p = 0.12$). Arrow indicates date of Hurricane Irene (15 October 1999). Data missing at Pinnacle for 11/1999.

Statistical analysis—Abundance data were arcsine square root transformed prior to analysis. Two-way analysis of variance (ANOVA) was used to test for differences with date and site as fixed factors. When significant differences were found, Tukey's multiple comparisons were used to test for differences within factors. Because fragment size and weight data proved non-normal, standard parametric statistical analyses were not possible to assess differences between sites and dates. Additionally, the paucity of fragments present at Shallow Conch during the week after storm impact prevented non-parametric statistical analyses of fragment size and weight. Therefore, only means and standard errors of the data are presented and general trends discussed.

RESULTS—Species of *Dictyota* were the most prevalent algae at both Shallow Conch and Pinnacle between 1994–2000, covering up to 37.9% and 47.0% of the benthos, respectively (Fig. 1). Although abundance varied significantly over time ($p = <0.0001$, $F = 33.74$, $n = 9$), no trend indicating an increase or decrease of

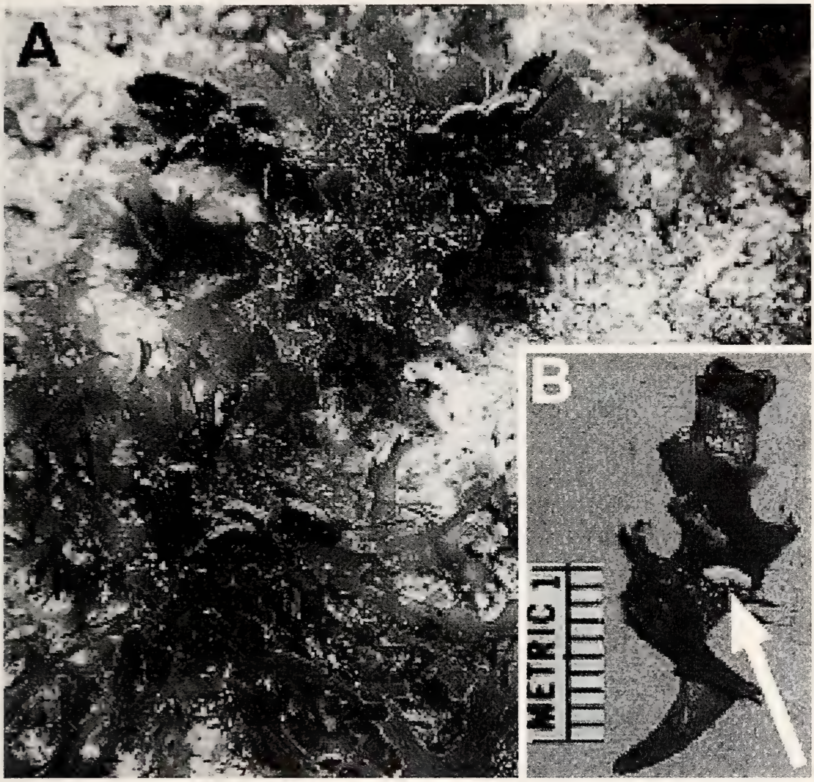

FIG. 2. *Dictyota menstrualis* and *D. pulchella*. A. *In situ* overgrowth of many benthic species including *Halimeda tuna* at one month after Hurricane Irene. B. Fragment of *Dictyota menstrualis* from Shallow Conch showing sand particle (see arrow) to which it had attached in <2 d under laboratory conditions. Scale bar = 1 cm.

population size was obvious (Beach et al., 2003). No significant difference existed in percent cover of *Dictyota* spp. between the two sites ($p = 0.122$, $F = 2.41$). Populations of *Dictyota menstrualis* averaged 3.6 times denser than *D. pulchella* at Shallow Conch, and 3.3 times denser at Pinnacle (Beach et al., 2003), but the two species commonly intertwined with one another as they overgrew sandy substrates and benthic organisms such as red algal turf, *Halimeda* spp. (Chlorophyta), and sponges (Fig. 2).

Water motion generated by Hurricane Irene severely scoured both study sites, leaving behind large bare patches and areas of cropped turf algae. At Shallow Conch, *Dictyota* spp. cover was reduced to one-eighth of the pre-hurricane densities seen two months before storm impact, and Pinnacle populations were reduced to one-third of pre-hurricane densities (Fig. 1). In the days following storm impact, the fragment pool at Pinnacle was 45× greater (0–25 fragments/0.25 m^2) than at Shallow Conch (0–2 fragments/0.25 m^2). Under non-hurricane conditions, it was 2× higher at Pinnacle than Shallow Conch (Fig. 3a). At Shallow Conch, the number of fragments collected during the first three days after the storm was >5× lower than during

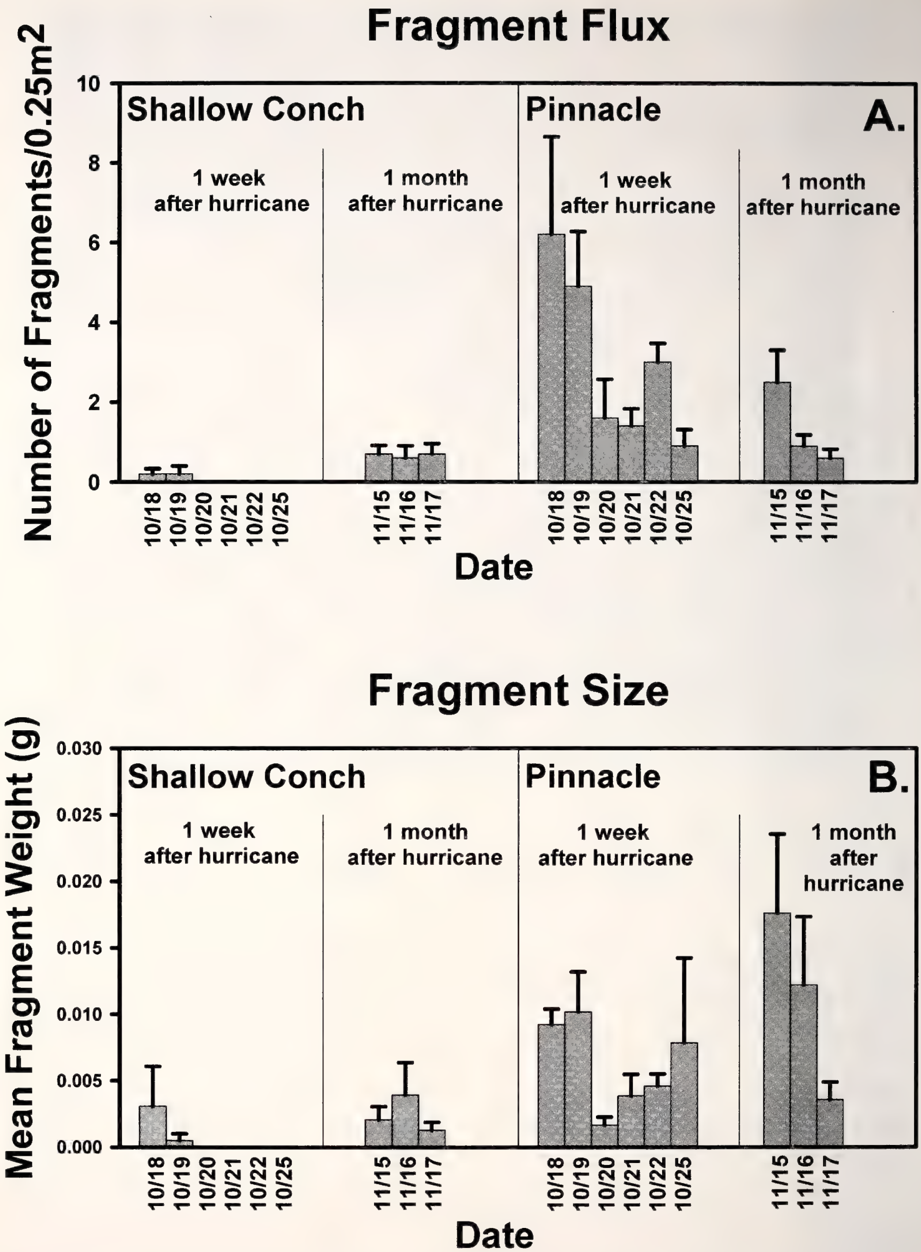

FIG. 3. Number and weight of *Dictyota* spp. fragments collected one week and one month after Hurricane Irene (mean ± SE). A. Number of fragments collected/0.25 m^2 at Shallow Conch and Pinnacle. B. Fragment weight.

TABLE 1. Survival and attachment of hurricane generated fragments of *Dictyota* from Conch Reef, Florida Keys.

	48 h after hurricane (n = 20 quads d^{-1})	48 h to 1 wk post hurricane (n = 100 quads in 5 d)	1 month after hurricane (n = 40 quads d^{-1} in 2 d)
% of all fragments that were viable*	100	97	100
Mean days to attachment (± SE)*	n/a	1.22 (±0.10)	1.09 (±0.09)

* Fragment data pooled from two sites: Shallow Conch and Pinnacle.

non-hurricane conditions (Fig. 3a). Alternately, at Pinnacle, the number of fragments was >3× higher after the storm than a month after hurricane impact (Fig. 3a).

Immediately following hurricane impact, fragments of *Dictyota* ranging in size from small apical tips (~3 mm in length) to large "tumbleweeds" (several cm in length) were observed in the water column. However, average fragment size as determined by weight was half that found under non-hurricane conditions (Fig. 3b) at both Shallow Conch and Pinnacle. Fragments at Pinnacle tended to be twice as large as fragments at Shallow Conch both after the hurricane and under non-hurricane conditions (Fig. 3b).

The sinking rate of fragments one dichotomy or less in size (typical of most storm generated fragments; Fig. 3b) was highly variable and depended upon fragment orientation in the water column. When caught in the fast moving currents observed after hurricane impact (>1 knot, PV, personal observation), these fragments could remain suspended in the water column for several days (PV, personal observation) and potentially transported vast distances. The majority of storm-generated fragments were viable, and most attached to the substratum within two days for both sites (Table 1; Herren et al., in press). Within a month after hurricane forces almost eliminated *Dictyota* spp. from our study areas, percent cover recovered to half of pre-hurricane conditions (up to 22% cover at Shallow Conch, Pinnacle data unavailable, Fig. 1), while abundance of all other reef organisms remained consistently low.

DISCUSSION—Our data suggest that storm-generated water motion shreds populations of *Dictyota menstrualis* and *D. pulchella*, creating myriad fragments that survive and reattach, thus aiding in rapid population recovery with the return of typical field conditions (Fig. 1, 3; Table 1; L. J. Walters, unpublished). The ability of these fragments to produce attachment structures faster than the other common reef macroalgae at Conch Reef (Fig. 4), combined with the rhizoidal holdfasts possibly left intact after the hurricane, allow *Dictyota* fragments to effectively "reseed" populations, leaving them poised for explosive growth. Although the percentage of new individuals of *Dictyota* spp. produced from intact holdfasts or from fragments remains unknown, this study increases our knowledge about mechanisms associated with *Dictyota* population recovery. When combined with decreased herbivory and increased nutrient regimes, fragmentation via physical disturbance may be key for understanding rapid recovery of *Dictyota* species. Additionally, hurricanes, including Category I storms such as Hurricane Irene, may have the potential to increase greatly

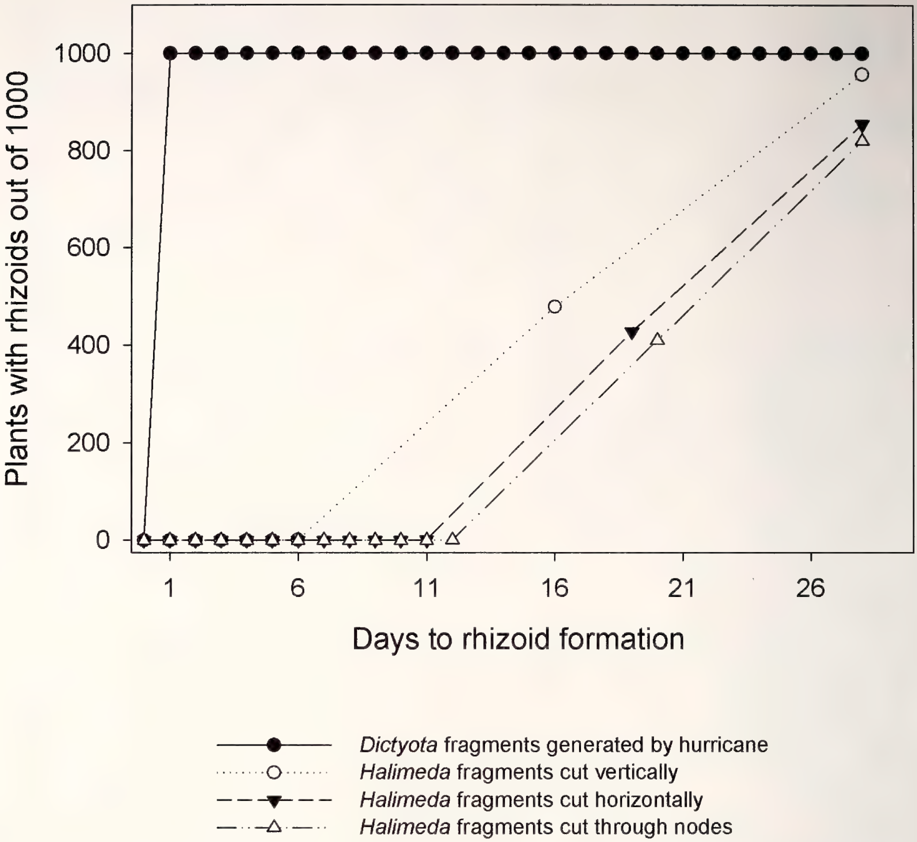

FIG. 4. Predictive model of *Dictyota* spp. (this study) and *Halimeda* spp. (Walters and Smith, 1994) fragment success at Conch Reef, Florida Keys.

the latitudinal and depth distributions of *Dictyota* species by transporting fragments. Water motion generated by the storms sheared the thin-bladed tissue, producing fragments that drifted in the water column for variable amounts of time before settling and reattaching to the substratum.

Fragmentation exponentially boosts the apparent size of a population without sexual reproduction. Fragmentation may explain observed blooms of other algae following storm disturbances: *Liagora* sp. after Hurricane Hugo in Guadeloupe Island, FWI (Bouchon et al., 1991), *Trichosolen* sp. after Cyclone Gavin in Fiji (Littler and Littler, 1999), and *Trichosolen molassensis* after a ship grounding at Molasses Reef (Littler et al., 1987). Although the concept of fragmentation is well understood from cultivation practices for many algae (Rodriguez, 1996), fragmentation rarely has been considered as a major means of propagation and dispersal *in situ* for tropical reef algae (but see Kilar and McLachlan, 1986; Santelices, 1990; Norton, 1992). The best exception to this generalization may be the nearly two decade-long spread of *Caulerpa taxifolia* (Chlorophyta) in the Mediterranean (Olsen, 1997; Ceccherelli and Cinelli, 1999; Smith and Walters, 1999). Nevertheless, the role of weather-induced physical disturbance in producing viable fragments of tropical algae and their role in subsequent community recovery remain poorly characterized (Walters and Smith, 1994).

A decade of field observations on tropical reefs in the Caribbean Basin has documented episodic, rapid increases of *Dictyota* spp. (Lirman and Biber, 2000; Williams and Pulunin, 2001) after local disturbances such as anchor damage (Creed and Filho, 1999), hurricanes (Quirolo, 1998), and shipwrecks (Wheaton et al., 1994). Other studies have documented large increases in *Dictyota* spp. biomass without an apparent cause. For example, *Dictyota* spp. are the only algae present at all sites on Molasses Reef, Florida (Eiseman, 1981), and have become dominant (4.9 kg dry wt m^2 or 77.9% of biomass) in benthic communities in the Fernando de Noronha Archipelago, Brazil (Pereira et al., 1996). *Dictyota* spp. are also part of a 20% increase in algal abundance during a 7-yr study off San Blas, Panama (Shulman and Robertson, 1996), are part of a 315% increase in algal abundance in a 25-yr study off Belize (McClanahan and Muthiga, 1998), and are the dominant cover in a multi-site study of the Caribbean basin (Williams and Polunin, 2001). What allows species of *Dictyota* to increase in population size so rapidly after disturbance?

Almost 100% of fragments from species of *Dictyota* from Key Largo developed attachment rhizoids in a little over a day of generation (Table 1). This rhizoid production rate was 6–11× faster than in *Halimeda* (Walters and Smith, 1994), giving *Dictyota* a competitive edge over this other common macroalgal genus in the Florida Keys (Fig. 4). The quick production of rhizoids combined with the estimated time fragments remained in the water column probably allowed *Dictyota* to develop rhizoids while sinking towards the benthos, poising fragments for immediate attachment upon reaching suitable substrate. This is the first time that rhizoid production has been considered as a mechanism for blooms of weedy species, and data presented here can be combined with data from Walters and Smith (1994) to create predictive models of *Dictyota* and *Halimeda* at Conch Reef after hurricane activity (Fig. 4). To produce this model, fragment success was defined by two variables: “r” was the percentage of fragments that generated rhizoids while $F_{generated}$ refers to the total fragments generated by the hurricane, and F_{lost} refers to the number of fragments exported out of the system into deeper water.

$$\text{Fragment success} = r[(F_{generated} - F_{lost})] \tag{1}$$

Because the wound orientation of fragments is known to affect rhizoid production rates in *Halimeda*, the equation can be broken down still further. For instance, in Walters and Smith (1994), fragments produced from vertical cuts in the thallus that mimicked fish bites were more successful than fragments produced from horizontal cuts that mimicked storm damage (Fig. 4).

$$\text{Fragment success} = r[(F_{storm\ generated} - F_{lost}) + (F_{grazing\ generated} - F_{lost})] \tag{2}$$

Whether increases in percent cover of *Dictyota* spp. after physical disturbance have occurred naturally for many years and are only now becoming recognized, or whether this is a recent phenomenon that occurs in impacted or degraded ecosystems remains unknown. However, possible explanations for the weedy status and Caribbean-wide increase in cover by *Dictyota* spp. include the dieback of the herbivorous sea-urchin *Diadema antillarum* (Hughes et al., 1987; 1999), anthropogenic nutrient addition to the ecosystem (Lapointe, 1997, 1999), rapid rates of photosynthesis (Peckol and Ramus, 1992; Raven and Osmond, 1992), and protection from certain grazers via inducible or constitutive secondary metabolites (Cronin and Hay, 1995, 1996; Hardt et al., 1996; Herren et al., in press, although some fish can consume the tissue, Paul et al., 1988; Paul et al., 1990). Until the present study, however, the underlying disturbance-mediated mechanisms leading to an increase in abundance were poorly understood. On Conch Reef, mechanical disturbance via hurricanes produces vegetative fragments and clears substrate, key factors that when combined facilitate *Dictyota* spp. propagation, and may lead to rapid population recovery. Additionally, because of the die-back of the herbivorous sea urchin *Diadema antillarum* in the Florida Reef tract, species of algae not preferred by herbivorous reef fishes may have become dominant. Subsequently, these macroalgal species may have the potential to explode unchecked, thus underscoring the complexity of biological cycles that are altered as a result of the natural loss of a single, keystone grazer.

Although storm intensity is an important factor for creating fragments and opening substrate, the direction of storm movement may also be an important variable in *Dictyota* spp. dispersal. As witnessed here, currents move fragments away from certain locales (eg. Shallow Conch), and deposit them in other areas (eg. Pinnacle; Fig. 3). Two Category 5 and 15 Category 4 hurricanes have made landfall on the East coast of the United States during the past century (see http://www.aoml.noaa.gov/hrd). In contrast, lower energy storms are more common in the Caribbean Sea and western Atlantic Ocean, with an average of 10 tropical storms, six hurricanes, and two major hurricanes each year (Category 3 or higher) in the United States. In the 1999 hurricane season alone, eight hurricanes hit the Caribbean – Atlantic region, with Hurricane Irene being one of the weakest. Hurricanes in this region can be grouped into three broad categories according to track direction: 1) east to west (typical movement), 2) west to east, and 3) south to north (typical October storm of the 1930s and 1940s). Such storms, and the subsequent currents they produce, have the potential to inject fragments into the northward flowing Gulf Stream for eventual settlement in distant coastal habitats, thus influencing the distribution and genetic attributes of *Dictyota* spp. populations along the southeast coast of the US. Alternatively, fragments may be deposited into the shallow areas of Florida Bay and subjected to viability-reducing sand scour or are carried into the Gulf of Mexico where fragments would fall beyond the photic zone. More studies are needed to understand the relationship between hurricane force, direction, and viability of fragments for reef algae. For instance, Quirolo (1998) reports a bloom of *Dictyota* spp. covering "most everything" within a month of Hurricane George (Category 5, east-to-west track) making landfall in Key West in 1998, but no indication of the mechanisms responsible for this increase in biomass are provided.

The mechanisms driving algal blooms on tropical reefs remain complex and highly debated (Hughes et al., 1999; Lapointe, 1999). Recent studies suggest that both increased nutrient levels and reduced herbivore pressure can lead to increased macroalgal abundance (Miller et al., 1999; Smith et al., 2001; Thacker, 2001). This study provides evidence for yet another factor, physical disturbance, which can promote rapid algal growth via population propagation through fragmentation.

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ELEMENTARY PARTICLE MASS SUB-STRUCTURE POWER LAW

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ABSTRACT: *A simple numerical basis for estimates of microquanta of mass and 1/6 charge in elementary particle sub-structures is observed in tables of Standard Model (SM) data. An equation for these relations yields whole particle masses and conserved charges consistent with the SM for the quarks, for their anti-quarks, and for the leptons. This arises in the equation by a sixth power of the number of the micro-components, with systematicly derived departures from a constant coefficient of two thirds of the mass quantum (with modification for one case.) This observation of a new type of power law basis for systematic regularity in particle structures parallels to a degree some recent theory attempts. The link to empirical data for the general class of theoretically hypothesized sub-particles provides a new point of departure for further particle definition, and for study in the proliferation of particles and on the means of neutrino mass oscillation. There are further predictive implications.*

Key Words: leptons, quarks, electrons, particle sub-structures, mass power law, regularity of masses, neutrino oscillations, proliferation of particles, hadrons, baryons, composite particles

THE existence of charges of 1/3 in the Standard Model (SM) quarks (Eidelman et al., 2004) has led numbers of physicists to theorize about preon/parton-like sub-particles of which all atomic particles, including quarks and anti-quarks, would be composed (*e.g.:* Haisch et al., 1994; Treiman, 1999; Salam. 2000; Bandos et al., 2001; Dugne et al., 2002; Luty and Mohapatra, 1997; Kim, 1998; Gsponer and Hurni, 1996; Bergshoeff et al., 1988; Pati et al., 1981; Pati and Salam, 1983.) Also, there have been many efforts, including those within the international Particle Data Group (PDG) (Manohar and Sachrajda, 2004), to define masses and mass ratios for quarks and leptons (*e.g.:* Treiman, 1999; Salam, 2000; Bahcall et al., 1998; Rodejohann, 2002; Fukuda et al., 2000). These difficulties lie at the third and second levels, respectively, below the atom in sub-atomic particle structure. The approach here-in to those deeper problems (concerning the conventionally elementary particles of the second level) begins at the first level below the atom with the SM hadronic particles like those that combine to make up the atomic nucleus itself, the main massive body of the atom. Guided by the number and mass relations of the well known first-level hadron particles to their second-level quark and anti-quark component particles, this research note next considers mass and charge relations between the SM second-level particles and a possible third level quantal sub-structure, to resolve the lower level particle mass and charge difficulties cited. Then, examples connect all three levels to

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re-interpret mass and charge problems in some known particles at each level, and point out a resulting approach to correlation with other important particle properties.

Looking at SM meson and baryon particles (hadrons) which are widely accepted as composites of quark/anti-quark components (Amsler and Wohl, 2004), this research note observes in their empirical data a numerical composite sub-structural relation indicating a systematic mass increase for the hadrons relative to the sums of the PDG listed empirical masses of their components (Eidelman et al., 2004). The equation for this relation can then be logically extended to the SM leptons and quarks/anti-quarks (LQ). Trials in those LQ classes of conventionally elementary particles yield estimates of component sub-structures with new microquanta of mass and conserved 1/6 fractional charge within particle masses matching the SM values. As in the hadrons, these LQ particles would typically have masses greater than the sums of masses of their components in accordance with the numerical composite relations of the generalized equation. The equation indicates this typical mass increase in the LQ classes of particles, first, by a directly interpretable fifth power of the number of the components. Then, after collection of terms with defined limitations, the particle masses are resolved by a simplified sixth power law, with systematicly derived departures from a constant coefficient equal to two thirds of the mass microquantum. This is modified in the one extreme case of the electron neutrino. This power law, only distantly similar to some recent theory (*e.g.*: Haisch et al., 1994; Kim, 1998; Bandos et al., 2001; Luty and Mohapatra, 1997), provides a new basis for systematic regularity of the quarks/anti-quarks and leptons in particle masses and quantal composite sub-structures with conserved charge. The link to empirical SM particle data for composites is a phenomenological departure point for reorganizing and retesting such particle aspects as uncertain quark masses (Manohar and Sachrajda, 2004), neutrino mass oscillations (Bahcall et al., 1998; Rodejohann, 2002; Fukuda et al., 2000), etc., in theories and experiments of particle physics. There are further predictive implications, including (in the appendices) a simpler regularity in some proliferations of hadronic particles and in neutrino oscillations.

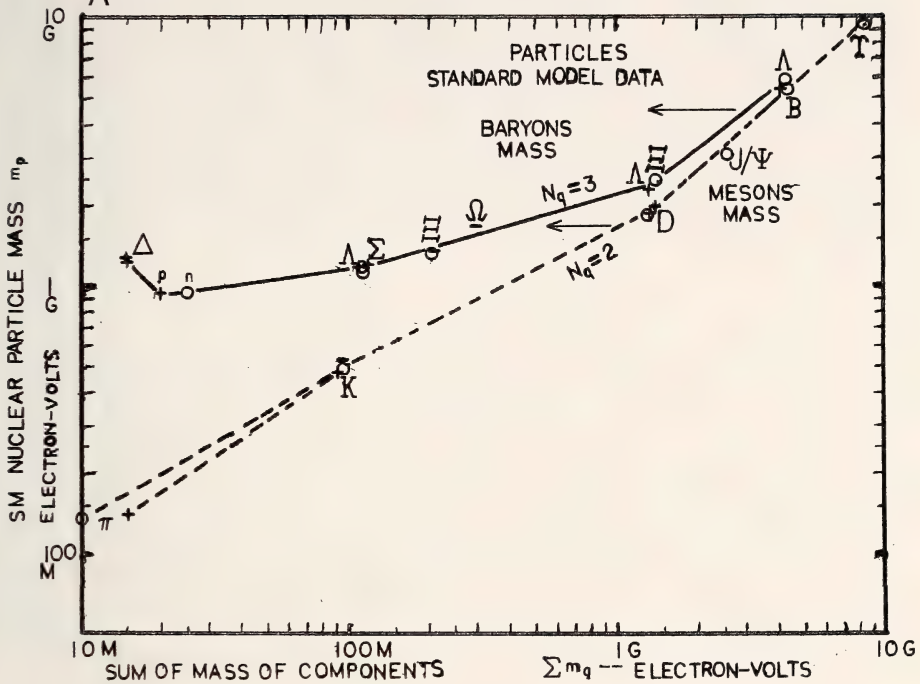
A SUB-STRUCTURAL EQUATION FOR COMPOSITE MESONS AND BARYONS—Figure 1A displays current SM data from the PDG (Eidelman et al., 2004) on the larger nuclear particles which are well known from typical overviews in the literature (*e.g.*: Close et al., 1987; Treiman, 1999) to be composites of quarks/anti-quarks. The two curves show whole particle masses in electron-Volts for the baryons (3 quark components) and mesons (2 components, quark and anti-quark, of the quark class (q) of particles.) These particle masses are plotted against the sums of the known component quark/anti-quark masses.

→

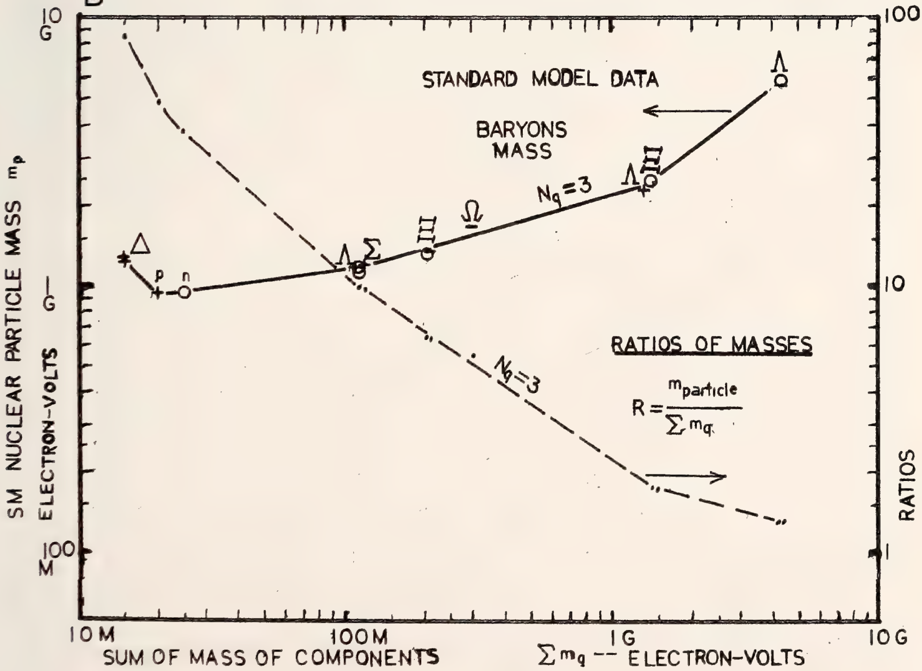
FIG. 1A. The masses of common Standard Model hadron particles are graphed against the sums of the separate individual masses of the 2 or 3 component quark class (q) particles, quarks or anti-quarks, for each case. Circles indicate neutral particles; minuses and pluses indicate charges. Anti-particles may be overlaid. Including the neutron (n) and the proton (p), particles are indicated by the Greek and English letters as a common form of their names.

FIG. 1B. The heavier baryons are re-graphed with the ratios of their particle masses to the sums of masses of the 3 component quarks in each case.

A


PARTICLES
STANDARD MODEL DATA
BARYONS
MASS
MESONS
MASS
$N_q=3$
$N_q=2$
SM NUCLEAR PARTICLE MASS m_p
ELECTRON-VOLTS
SUM OF MASS OF COMPONENTS
Σm_q -- ELECTRON-VOLTS
10M
100M
1G
10G

B


STANDARD MODEL DATA
BARYONS
MASS
$N_q=3$
RATIOS OF MASSES
$R = \frac{m_{particle}}{\Sigma m_q}$
RATIOS
SM NUCLEAR PARTICLE MASS m_p
ELECTRON-VOLTS
SUM OF MASS OF COMPONENTS
Σm_q -- ELECTRON-VOLTS
10M
100M
1G
10G

In Figures 1B and 1C two additional curves show the ratios R of those SM whole particle masses m_p to those sums $\Sigma\, m_q$ of component quark/anti-quark masses for well known sample particles of the two types of hadrons. (Here q refers to the quark/anti-quark class of components without distinction between them at this point since those of the same type would normally have the same mass, though opposite in charge.)

Graphing these SM baryon and meson data in this way reveals (Fig. 1D) that the varying numerical relations between the composite particle masses and the SM quark/anti-quark sub-structure masses in both these types of hadrons fit a single derived simple function

$$R = m_p \Big/ \sum m_q = N_q^{\,y}. \tag{1}$$

This relation equates the ratios to the N number of component quarks/anti-quarks (fixed at 2 or 3 for each curve) raised to a positive y power, which varies with the sums in an exponential law. That law identifies the SM mass increase ratios for hadron particles over the summed masses of the quark/anti-quark components within the particles. These ratios fall toward +1 in Figure 1D for both types of the SM heavier hadrons (listed at the bottom of Table 1.) In the two-part curve y is plotted for whole number and fractional values derived from the two unsmoothed ratio curves, with small discrepancies from a single regular curve. With the lighter component sums, in both Figure 1D and its continuation in Figure 2A, the value of the exponent y appears to be crossing the value of 4 and asymptoticly approaching the value of 5.

Extension of the Sub-Structure Equation Relations to the Elementary Quarks/Anti-Quarks and Leptons—*General overview*—It was next observed that this apparent limiting value of $y = 5$ in the generalized composite sub-structure equation (1) can then be extended toward still lower mass sums of components, as shown in Figure 2A, to apply to more nearly elementary SM particles which (unlike the hadrons) are not composites of quarks/anti-quarks. Specificly, these particles are the quarks themselves, with their anti-quarks of similar masses and opposite charges, and the leptons, including the neutrinos.

Steps in this further application of the composite structure equation are outlined in Table 1 for reference as this discussion proceeds. The tabulated sets of resulting calculated masses for the more elementary LQ particles and their ratios of mass increase (over the estimated sums of component masses) are graphed in Figure 2A against those sums of component masses, as in the other figures. The range of LQ particle masses overlaps and greatly exceeds the range of the hadron masses, as it

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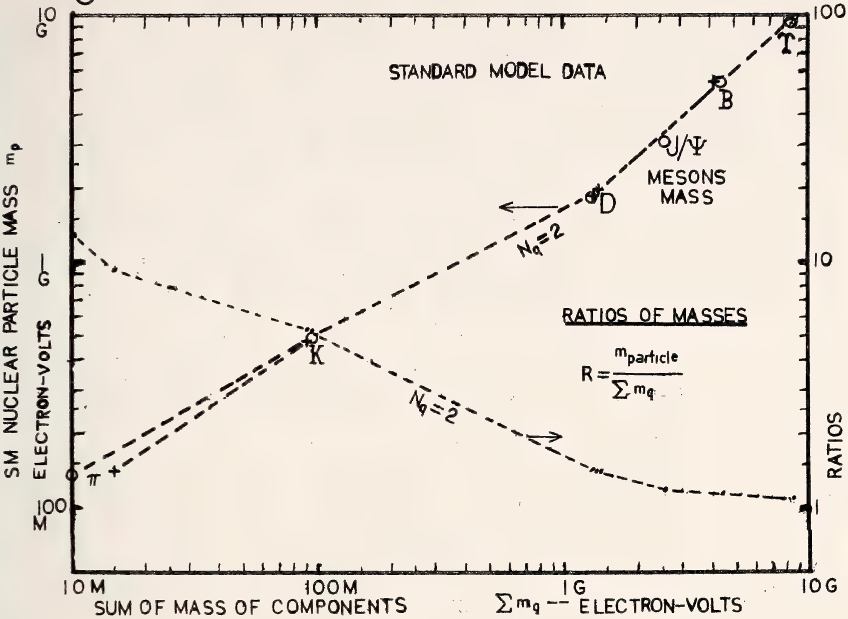
Fig. 1C. The lighter mesons are re-graphed with the similar ratios for their 2 components (q), 1 quark and 1anti-quark, in each case.

Fig. 1D. Particle masses follow a simple composite sub-structural relation equation for the Standard Model particles composed of several quarks/anti-quarks. The exponent for the number of quark-class (q) components in the equation is essentially the same for both the 2 and 3 quark/anti-quark particles at each component sum level. But the exponent varies systematicly across the range of sums, apparently crossing the value of 4 and approaching the value of 5 with the lighter component sums.

C


STANDARD MODEL DATA
MESONS MASS
RATIOS OF MASSES
R = m_particle / Σ m_q
SM NUCLEAR PARTICLE MASS m_p
ELECTRON-VOLTS G—
RATIOS
SUM OF MASS OF COMPONENTS
Σ m_q -- ELECTRON-VOLTS
10M
100M
1G
10G

D

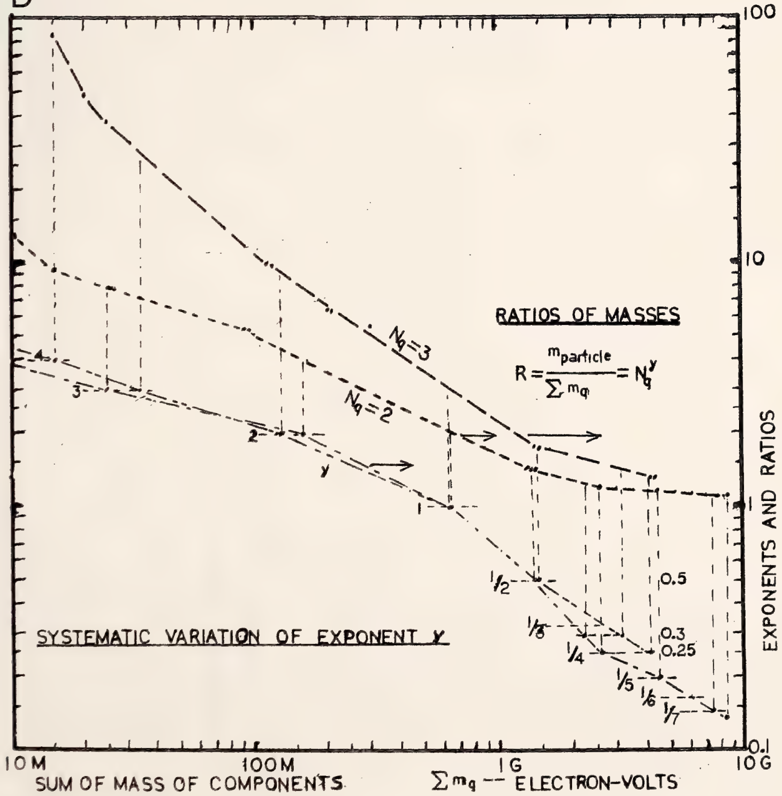

RATIOS OF MASSES
R = m_particle / Σ m_q = N_q^y
SYSTEMATIC VARIATION OF EXPONENT y
EXPONENTS AND RATIOS
SUM OF MASS OF COMPONENTS
Σ m_q -- ELECTRON-VOLTS
10M
100M
1G
10G

TABLE 1. 2004 PDG Standard Model (SM) and computed particle masses.

Particle/alternate options	Charge	SM Mass eV	No. parts	Mode	Pairs	Sum mass eV	Ratio m_p/Sum	Calc. mass	Deviations eV;	%
Electron neutrino	0	< 3 eV	2	E (Extr)	1 +−	21.905 eV	0.111	2.43388 eV	Zero	0%
Self anti-neutrino—identical data										
Neutrino/gluon options available to nature, typical, non-SM.	0		4	E	2 +−	43. 81 eV	0.111	4.8677 eV	NA	
			4	E	1++,1−−	"	"	"	"	"
			4	E	1++−, 1−	" (triplet)	"	"	"	
			4	E	1+−−, 1+	" "	"	"	"	
			6	E	3+−	65.715 eV	"	7.3016 eV	"	
			6	E	1−−, 1++, 1+−	"	"	"	"	
			2	M(Med.)	1+−	21.905 eV	0.333..	7.3016 eV	"	
			4	M	2+−	43.81 eV	"	14.6033 eV	"	
			4	M	1++, 1−−	"	"	"	"	
			6	M	3+−	65.715 eV	"	21.905 eV	"	
			2	U(Usual)	1+−	21.905 eV	10.69	234.13 eV	"	
			4	U	2+−	43.81 eV	341.33	14953.8 eV	"	
Muon neutrino	0	<0.19 MeV	6	U	3+−	65.715 eV	2592	0.1703 MeV	Zero	0%
Self anti-particle—identical data										
Electron e−	−1	0.511± MeV	6	U	3−−	"	7776	0.511 MeV	Zero	0%
Positron e+	+1	"	6	U	3++	"	"	"	"	"
Tau neutrino	0	<18.2 MeV	12	U	1++, 1−−, 4+−	131.43 eV	138241	18.169 MeV	"	"
Self anti-particle/options, typical			8	U	2+−, 1++, 1−−	87.62 eV	21844.3	1.914 MeV	"	"
			10	U	1++, 1−−, 3+−	109.525 eV	60000	6.5715 MeV	"	"
			12	U	6+−	131.43 eV	82934	10.9 MeV	"	"
Up quark (current mass)	+2/3	1.5–4.0 MeV	8	U	3++, 1−−	87.62 eV	32768	2.871 MeV	"	"

TABLE 1. Continued.

Particle/alternate options	Charge	SM Mass eV	No. parts	Mode	Pairs	Sum mass eV	Ratio m_p/Sum	Calc. mass	Deviations eV;	%
Anti-up quark/option	−2/3	"	8	U	2−−, 2+−	"	21844	1.914 MeV	"	"
Down quark (curr. mass)										
	−1/3	4–8 MeV	10	U	1−− 4+−	109.525 eV	46666.6..	5.11 MeV	"	"
Anti-down quark/option	+1/3	"	10	U	2++, 1−− 2+−	"	73333.3..	8.032 MeV	0.032MeV;	0.4%
Strange quark (curr. mass)	−1/3	80—130 MeV	14	U	4−−, 3++	153.335 eV	537822	82.467 MeV	Zero	0%
Anti-strange quk/option	+1/3	"	16	U	2++, 1−− 5+−	175.24 eV	611669	107.19 MeV	"	"
Muon	−1	105.7 MeV	16	U	3−−, 5+−	175.24 eV	611675	107.2 MeV	1.5 MeV;	1.5%
Anti-muon	+1	"	16	U	3++, 5+−	"	"	"	"	"
Charm quark (run'g mass)	+2/3	1.15–1.35 GeV	22	U	6++, 4−−, 1+−	240.955 eV	4.84 M	1.1665 GeV	Zero	0%
Anti-charm quark/opt'n	−2/3	"	24	U	4−−, 2++, 6+−	262.86 eV	5.31 M	1.395 GeV	0.045 GeV;	3.3%
Tau particle	−1	1.777 GeV	24	U	6−−, 3++, 3+−	"	6.125 M	1.744 GeV	0.033 GeV;	1.9%
Anti-tau	+1	"	24	U	6++, 3−−, 3+−	"	"	"	"	"
Bottom quark (rn'g mass)	−1/3	4.1–4.4 GeV	28	U	5−−, 4++, 5+−	306.67 eV	13.113 M	4.0218 GeV	0.0787GeV;	1.9%
Anti-bottom quark/opt'n	+1/3	"	32	U	1++, 15+−	350.48 eV	12.583 M	4.4106 GeV	0.0101GeV;	0.23%
Top quark (ave. mass)	+2/3	174.3± 5.1 GeV	52	U	10++, 8−−, 8+−	569.53 eV	305.56 M	172.1 GeV	Zero	0%
Anti-top quark/option	−2/3	"	54	U	7−− 5++, 15+−	591.435 eV	289.1 M	170.986 GeV	"	"
Sample of SM Mesons and Baryons (Fig 1A.)										
Upsilon	0	9.460 GeV	2		b, anti-b quarks	8.5 avg GeV	1.113			
Bottom lambda	0	5.624 GeV	3		u, d, b quarks	4.315 " GeV	1.303			

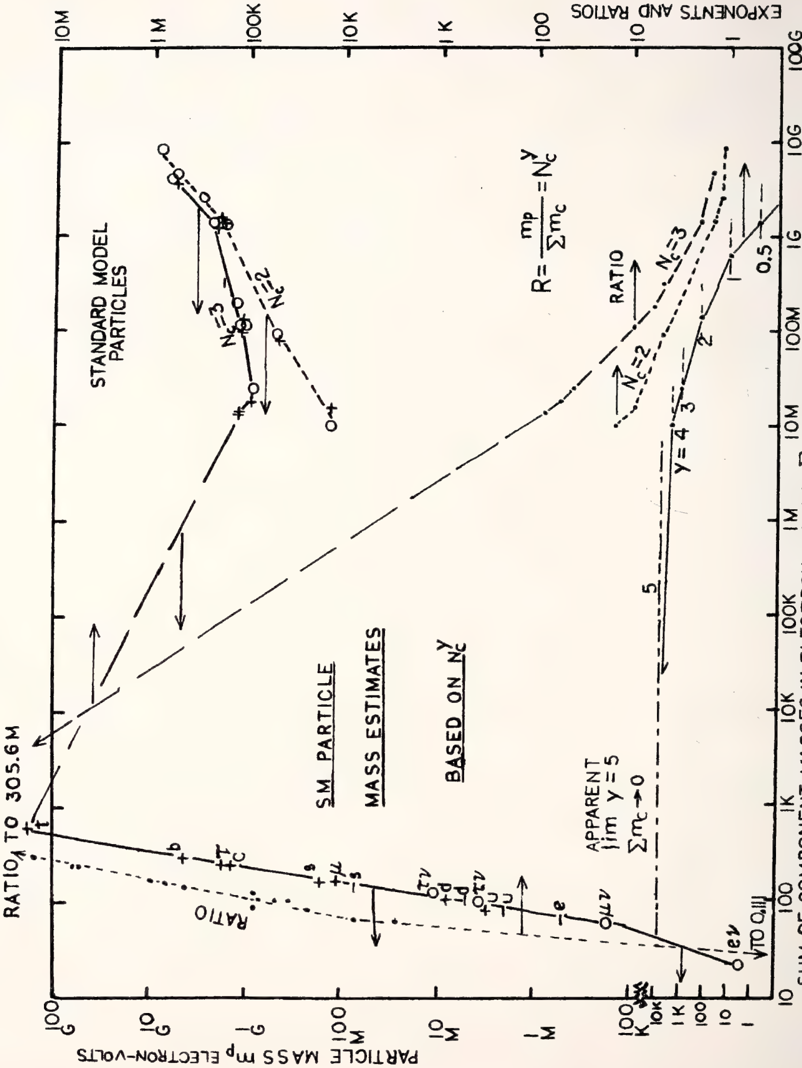


FIG. 2A. The composite equation can be extended to very small component sums, with the asymptotic exponent value of 5, to estimate quantal sub-structure components and particle masses in electrons, neutrinos, other leptons, and quarks or their anti-quarks. The ranges of particle masses and mass ratios far exceeds those from Fig. 1D.

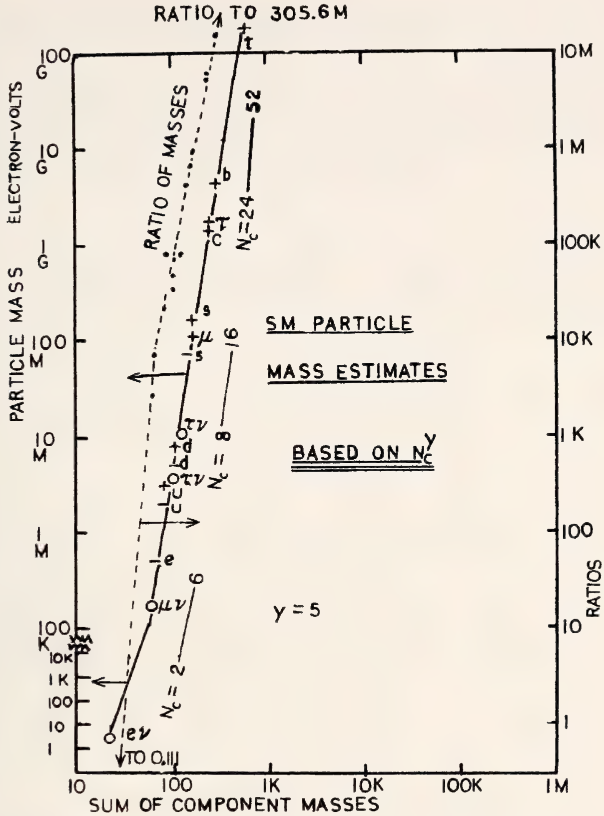


FIG. 2B. Separate view of the lepton and quark mass estimates graph in Fig. 2A. The ranges of numbers of quantal components required by the systematic regularity of these estimates is added.

does in the SM and the PDG listings (Eidelman, et al., 2004), while the sums of component masses are much lighter than before. In balance, the number of implicated microquantal components ranges to much larger numbers than the prior two or three hadron components, as shown in Figure 2B. Thus *N* becomes the variable of the generalized equation in this application as a fixed exponent power law.

The last column of Table 1 shows that all but six of the listed masses newly derived from the power law equation for SM particles (and their anti-particles) are within the PDG-accepted range of the empirical data (Eidelman et al., 2004). Two of the six are shown as alternative options in mass for the anti-particles that usually would be listed with the same mass as their primary options, which in these two cases have no deviations. The deviation from the SM data of one of these two alternates is less than 0.5%; the other has the largest deviation listed at 3.3%. Three others of the six deviant cases are within 2% of the SM/PDG empirical data, and all are within 3.3%. One is within 0.25%. The three with the largest deviations are among the larger particle/anti-particle sets above 1000 MeV (1.0 GeV) in mass. No other small integral value of the exponent *y* than 5 was found to be as suitable for this particular process of particle mass estimate over the LQ range of SM particles.

(There is a single SM particle with a special adaptation exception in the most extremely light mass range to be discussed.)

Logical process—The estimated lepton and quark/anti-quark mass values displayed in Figures 2A and 2B and in Table 1 resulted from a series of trials (with the composite sub-structure power law equation) which identified and added three necessary elements:

Added Element 1—The electron's SM mass rounded off to 0.511 MeV was used with the equation (inverted as a power law) to calibrate approximately a uniform mass microquantum for universal components for all the LQ particles. A single mass quantum would be the simplest component base in natural composite structures. No other particle than the electron was found to be as suitable for this calibration of a uniform quantum mass with the equation. (The reason for this finding appeared later, in the determination of Element 3.)

Logical concerns with element 1 and its progression to element 2—The Standard Model (SM) (*e.g.,* Eidelman et al., 2004; Treiman, 1999) clearly does not include this kind of commonality of component microquanta implied by applicability of the sub-structural power law equation both to leptons, which can interact mutually via the SM weak force, and to quark/anti-quark components of hadrons, which can interact mutually via the SM strong force. It is initially observed here only that the mass properties involved in that application would be processed similarly across both LQ classes and that the resultant particle masses are generally consistent with the PDG listings.

However, the SM property of charge, which is conserved similarly in electrical interaction across both LQ classes, cannot be omitted from discussions of numbers of any possible components of the two classes since the simplest component system would carry and conserve charge in both classes by the same numbers of uniform components as mass involves. Such commonality of mass components with further charge implications is not necessarily contradictory to the SM and its definite distinction between the dissimilar weak and strong forces for the two different kinds of whole particles of the LQ classes. These unlike forces may possibly not be inherently carried by any mass quanta since neither of the two kinds of forces appears in the same way in the two classes of particles, but the property of mass does, and so does the conservation of charge. Furthermore, the universal microquantum of sub-structure implied here would be at one full structural step below the (second sub-atomic) particulate level of the leptons and the quarks/anti-quarks at which the force differentiations appear. It would be at two full steps below the (first sub-atomic) structural level of the hadrons, which bear the strong forces as composites of quarks/anti-quarks in different combinations. Thus, the different leptonic weak and hadronic strong forces would be beyond the scope of the sub-structural mass/number power law equation (except possibly to note that the integer charges of the leptons on the electron charge scale and the fractional charges of quarks/anti-quarks imply a significant difference between the overall internal conformational organizations of the two classes of particles, which might eventually correlate in some significant way with their two more specialized types of external force interactions.) To this point, only the numbers, masses, and charges of implied components of the particles are directly involved with the power law equation. Comprehensive conformational arrangements of the components are not similarly involved (with one simplest possible exception in form and number at the two component level, to be discussed next).

Element 2—Since neutral, positive, and negative charges, as well as 1/3 steps of charge, are required for various SM particles, the simplest components would be positive and negative 1/6 charge quanta, of the single uniform mass, appearing normally in conservingly organized pairs. Thus any particle can be neutral or of any multiple of 1/3 charge with only two basic kinds of components in the required number of these pairs. This conforms to the SM conservation of charge in all classes of particles. (Some of the larger derived particle masses involved in extremely high energy cosmic ray collisions could be more exact matches of the SM/PDG masses by allowing a singlet or single triplet option, not a pair. That kind of possible logical option is shown as two examples in the low mass, non-SM listings near the top of Table 1. This could sometimes yield a 1/6 level of overall charge, which is not permitted in the SM nor observed reliably.)

The simplest calibrating electron with its minus 1 charge would thus have 3 pairs made up of $N = 6$ negative 1/6 quantal components of conserved charge with mass at a rounded 10.9525 electron-Volts of mass each. That yields a 6 component $\sum m_c =$ 65.715 electron-Volts mass. This is multiplied by the 5^{th} power of 6 for the 0.511 MeV particle mass, listed in Table 1. The positron (electron anti-particle) is fully symmetrical with this. No other trial value of such a calibrated universal component mass and charge was found as suitable for deriving SM consistent masses of whole particles (other than hadron composites of quarks/anti-quarks, Fig. 1A.) Since the electron's components would all be negative in charge (and the positron's, all positive), their universal calibration was not affected by the third element found necessary with neutral particles or pairs.

Element 3—A key to the systematic logic of this element is that, in addition to functioning only at a lowest sub-structural level in all the lepton/quark classes of particles, the element does not vary in function with the leptonic interactions by entire particles through the weak force, nor with the hadronic contribution to interactions of other entire particles through the strong force. Neither does it vary in function with different electro-magnetic forces at changing velocities and separations of charges. The element deals primarily with PDG recognized and listed particle masses, integer numbers of generalized sub-structural mass quanta, their isolated plus or minus 1/6 electric charge quanta , and their idealized pairing of like or unlike charges for pair or particle neutrality or 1/3 steps of conserved charge.

A further key to Element 3 is a combination of three other observable features in the Table 1 list of the SM empirical masses of the LQ particles. Firstly, much larger numbers than 6 of self-neutral or plus and minus paired charge/masses would be necessary, even with the fifth power of the numbers, for the relative six orders of magnitude in mass above the mass of the electron for LQ particles of integral charges no greater than 1 or fractional charge.

Secondly, this range of masses includes all but two of the SM established LQ particles. One of these two is the completely neutral muon neutrino with a PDG empirical upper mass limit (Eidelman, et al., 2004) just above 1/3 the mass of the putatively completely charged electron. That is an oddly close mass relation for leptons, especially with the two of them of different types so close together at the low mass end of the six orders of magnitude of the usual range of LQ particle masses. (That is particularly odd in comparison with the only one remaining LQ particle at an extremely low empirical mass range beyond five orders of magnitude further removed below the usual range of LQ masses.) Taken together, these first two additional observations, with emphasis on the approximate 1/3 ratio of masses between the neutral muon neutrino and the integer charged electron, imply that these two particles may have exactly the same number of components with a factor of 1/3 in mass gain ratio for plus-and-minus neutral pairs in the muon neutrino compared to minus-minus charged pairs in the electron. That would also be the simplest mass relation between them. Both of these SM particles would retain the equation's fifth power U increase of mass over the sum of component masses, times this 1/3 factor for the neutral pairs only. And there would be no neutral pairs in the electron. In the course of this observational exploration, no other basis for application of the equation to neutral pairs was found as suitable as this 1/3 factor in reduced increase of neutral pair mass throughout the usual (U) range of SM masses of LQ particles. That observation initiates a new type of adapted application of the equation. This applies from the U empirical masses of the muon neutrino and the electron upward six orders of magnitude to the very large mass of the top quark.

(It should be noted that this 1/3 factor arises in part from realizing that there may be a mass for stated particles proportionately not very far below the empiricly well supported upper mass limits listed by the PDG, as distinct from the SM. Here, that possibility may be considered confirmed in a significant degree by the close fit to the SM of the resulting adaptation over such a large range of LQ particle masses with necessarily large numbers of quantizing options between neutral pairs and neutrally matched charged pairs. Accordingly, this non-restrictive bias toward an expected mass range not far below a PDG upper limit is applied herein to all three of the PDG upper mass limits for the SM neutrinos. Further related discussion is included in Appendix A on neutrino mass ratios.)

Thirdly, the anomalously small PDG upper mass limit of the SM electron neutrino shown in Table 1 makes it the only LQ particle whose mass is not considered within the U range. It is well below the U range at an extreme (E) separation from the empirical data for all other LQ particles by five additional orders of magnitude over the six within the U range. Furthermore, there could be an additional significant correlation of this well recognized (Eidelman, et al., 2004) large mass gap between the empirical upper mass limits for the two lightest neutrinos with other conflicting Notes within the formal PDG report (just cited). These notes include the PDG uncertainties about oscillations of the three SM/PDG neutrinos between different mass levels discussed in a PDG Note (Groom, 2004), the strong possibility of finding eventually a non-SM fourth kind (or more) of neutrino of uncertain flavor discussed in a PDG Note (Kayser, 2004), and the PDG Note (Olive, 2004) giving the cosmicly determined upper limit of total (or additively combined) mass for all types of stable light neutrinos as <24 electron-Volts. (There are a number of optional ways in Table 1 with which even this severe upper mass limit for all three neutrino masses added together might be met by applying this Element 3.) With those matters in view, together with the extreme lightness of the formal PDG Listings for the electron neutrino mass limit, a systematic variation of the power law relations expressed by the composite structure equation must be expected to occur in nature across this PDG gap to the lightest neutrino mass.

Possibly this could be due to a difference from the U mode (or level) of energetic interaction or binding between the particle's components, but that would be beyond the scope of the sub-structural mass/number equation of this research note. However, the equation would imply that such a low SM mass in the electron neutrino indicates a minimum number of the usual sub-structure components for the particle's neutral charge; that is, a single plus-minus pair. In addition, the extremity of this one, low mass, neutral case could be taken to imply a further E adaptation of the 1/3 mass gain rule for neutral pairs in two steps: Such as squaring the 1/3 fraction of the U rule for an E fraction of 1/9. And also reducing the U mass gain from numbers of components through reducing the power exponent y by the same 5 orders of magnitude as the separation between masses and bringing it to zero for an N power factor of 1 in this SM/PDG extreme range.

(Under this kind of change for the E case, the equation is no longer a strict single power law. It would at least have two states of the law for two different regions of application. A less adaptable alternative to fit this case could be to retain the strict fifth power of N and take the 1/3 fraction to its fifth power, with more complications at a later step and implications to be noted.)

These two E rule adaptations of the basic equation for the electron neutrino are somewhat legitimated by the previous 1/3 adaptation for neutral pairs over the entire U range of all the other LQ particles of the SM except the uniquely fully charged case of the electron/positron. With these adaptations, all the mass and charge relations of the established SM/PDG particles of the LQ classes could be described in one numeric quantal order under the U and E rules of Element 3 as detailed for the adaptations of the basic equation in the next section (which more numericly quantifies the logical U, E, and also the subsequent M, categories of this section and Table 1).

Natural regularity of LQ empirical masses in this numeric order rests essentially in the U range of masses. That must provide the basis for any extension into the E range. The numerical regularity of the quantized U neutral pair departures from the simplest original form of the equation (1) appears more clearly after collection of all the implied terms converts the equation to a sixth power law with systematicly regular departures, as is shown in the next section.

There are a few additional logical implications of the E application of the equation under the stimulus of the SM/PDG empirical particle mass data in Table 1. Even if the E rules are applied for the numericly possible neutral cases other than that of the SM electron neutrino with 2 components, up to as many as the 6 components assigned to the electron (as shown in the non-SM cases of Table 1), there would still be the same five order-of-magnitude gap from such non-SM E masses to the U masses, as shown by the E cases in Table 1. This gap could be taken to imply that nature may eventually be found to take the two steps of the E rules at separate points in the mass progression. That could create an intermediate or medium (M) group of non-SM particle mass options, such as those shown in Table 1. Similarly, nature might also close the gap from above in the U numeric mode with other available options in non-SM particles having masses derived from 2 or 4 components as listed in Table 1. These adaptations for such extremely small E neutral particles also led to the Table 1 options for charged pairs treated as neutrals and an equivalent option of singlets or triplets (all of which might in any use need slightly larger factors/coefficients.) That completes the discussion of the specific examples of Element 3 shown in Table 1.

However, there is logically a further inherent implication of Element 3 that if nature may (from the combined numeric and empirical possibilities) vary mass relations of neutral pairs by the square of the 1/3 rule, then consideration might be given to 1/3 cubed, or to an *i*th power of 1/3. These implications could provide a further regular progression of quantal mass options for even more extremely low mass neutral particles. Considerations of this kind are also made necessary by the PDG accredited Listings (Eidelman, et al., 2004) both of the extremely small empirical upper limit of mass for the electron neutrino and of non-exclusion of the possibility of mass for a non-SM version of the SM gluon (referred to in Table 1). Furthermore, the large body of on-going research in this range of particle masses cited by examples in Appendix A makes it clear that empirical and theoretical mass estimates well below the PDG upper limit for the electron neutrino (by 3 additional orders of magnitude) are no longer unusual in physics. (Other related matters are noted in Example 4 of Appendix C.)

Resultant more general form of the power law equation—In accordance with the stated logical process, equation (1) becomes

$$m_p = \left(\sum m_c\right) N_c^{\,y}\, F \tag{2}$$

and

$$F = (n_{\pm}/n) + (n_o/a\ n) \tag{3}$$

where $n_{\pm}$ is the number of negative and/or positive charged pairs, n_o is the number of neutral pairs, and as the sum of both kinds of pairs $n = N_c/\ 2$.

For U cases, $y=5$ and $a=3$. For E neutral cases under the E rules, $y=0$, and $a=3$ in denominators; but a changes to 1 if collected into numerators or non-fractions. Also in E cases F is divided by an additional departure factor of 3 to provide for the neutral 1/9 factor process of Element 3. (This is effectively equivalent to changing a to 9 in E cases.) For M intermediate neutral cases as shown, $y = 0$ (or more), and $a = 3$ in fraction denominators; but a may again change to 1 (or optionally 2) in numerators or non-fractions, without an additional departure divisor.

For all leptons (in the listed usual or normal PDG range and hierarchy) and quarks or anti-quarks, $\sum m_c = N\ m_u$, where $m_u = 10.9525$ electron-Volts for the universal microquantal mass component. (For the hadrons of Figure 1A, $F=1$, y is variable as shown, $N=2$ or 3, and the sum term varies with both component quark/anti-quark masses and N.)

Simplifying the equation—Computing limited to the lepton and quark/anti-quark masses of Table 1 is simpler, though less informative, with substitution and collection of terms in a new constant, C. F continues its influence. Thus,

$$m_p = 2n\ m_u(2n)^y(an_\pm + n_o)/an = (2^{y+1}/a)\ m_u\ n^y\ (an_\pm + n_o) = Cn^y(an_\pm + n_o), \tag{4}$$

where $C_U=(2^{y+1}/a)m_u=233.653$ eV $=2^5C_M=3\times 2^5\ C_E$ for U, M, E cases; and $C_M = C_U/2^5$; $C_E=C_U/(3\times 2^5)$.

The particle masses vary with systematic regularity, essentially as a power law with departures from a constant coefficient in accordance with the F factor due to neutral pairs and the M and E case rules. However, if calculated out in this form the departures of the coefficients from the 5 th power law are often large enough to equal the root of the power term times a smaller residual factor which varies systematicly with the ratio of neutrals to charged pairs and M, or E cases. In use that is less efficient for many cases than a further.simplification.

Further simplification to a 6 th power law for usual (U) cases—Since the LQ sum factor included an additional power of N, the equation becomes simpler in terms of N where $N_\pm$ and N_o are the numbers of components in charged or neutral pairs. Consequently,

$$m_p = N\ m_u\ N^y\{(N_\pm/N) + (N_o/aN)\} = (2m_u/a)\ N^{y+1}\ \{(a\ N_\pm/2N) + (N_o/2N)\}, \tag{5}$$

where the general E, M, and U case rules apply to a, y, and the special E divisor of 3. (Though applicable, the M, E cases are less intuitive in this format.)

The most significant change is that the power law exponent has become $y+1=6$. A factor 2 has also been moved to the constant factor from the bracketed F factor in order to shift its range of departure factors from (+ 1 to +3) to the range (+ 0.5 to +1.5) in the numerous U cases. The constant then becomes $(2/3)m_u$ for all cases. Before the shift of factor 2, the mean of the departure factor range was 2 and the average over about 30 U mass options matched to the SM was 1.9999148 . After the shift, that mean is 1.0 and the average is 0.9999579. The result is that overall only a negligible average departure from a strict power law would appear. Furthermore, since $N_o=N-N_\pm$, the bracketed F term can now simplify to $\{0.50+(N_\pm/N)\}$ or one half plus the fractional ratio of the charged pair components (or pairs) to all components (or pairs.) Thus, at the SM charge level for a lepton or quark/anti-quark, if no pairs of stated quantal components are charged pairs for a particular U mass value estimate (and in base rule neutral M cases), the factor of departure from a strict

6 th power law is 0.50. If half the pairs in U cases are charged pairs, then the factor is 1.0; there is no departure from an ideally strict sixth power law. If all pairs in the particle are charged, then the factor is 1.50. The decimal fraction is more conveniently used here since this relation is linear for the many other intermediate charged pair fractions for the larger particle estimates.

RESULTS—For quarks/anti-quarks and leptons of the full U range, including U case neutrinos, the simplest final equation is

$$m_p = (2\ m_u/3)N^6\{0.5 + (n_{\pm}/n)\}. \tag{6}$$

The mass of a U particle is determined only by the constant coefficient, the sixth power of the number of universal components, and the F departure factor of one half plus the ratio of the number of charged (non-neutral) pairs to the number of all pairs in the particle, charged and neutral. (For E or M neutral cases the special rules, exponent 0+1=1, and special E departure factor of 1/3 also apply.) In all forms of the equation the derived masses of Table 1 are the same if numerical roundings are the same.

DISCUSSION—This equation's built-in corrections for departures from a strict sixth power law of quantized particle masses can be of significant size for those standard particles which, under definite SM/PDG constraints of particle mass and charge, must be estimated with unequal or unbalanced numbers of neutral and charged pairs of quantal components. This is particularly true for the three most unbalanced particle cases (without alternative sub-structure options under SM/PDG constraints as restricted earlier for upper limits) which define the application of the stated law to the quarks/anti-quarks and leptons. These three are the low mass and very stable electron with no neutral pairs (all pairs charged), the somewhat lower mass muon neutrino with no charged pairs (all pairs neutral), and the extremely low mass electron neutrino with only one neutral pair (no charged pairs, all pairs neutral).

However, for the lepton and quark/anti-quark masses as a whole, departures from an ideally strict law of the sixth power of component number, by the adapted sixth power law here-in noted, are definitively constrained by the stated law equation (6) in an inherently systematic and regular way which is very simple for all but the electron neutrino. (This does include matching the extreme ratios of mass limits between the electron neutrino and other neutrinos as empirically defined by the authoritative PDG listings cited earlier. Appendix A collates ranges of data on neutrino mass ratios.) In the great majority of cases the derived mass estimate for the whole particle is also within the current SM constraints. The six deviations from 2004 SM/PDG values in Table 1 are low. (Two of these are low deviation options in cases that also have zero deviation options.) The LQ mass curve in Figures 2A and 2B is so steep on the balanced logarithmic scales that the small vertical departure corrections from a strict sub-structure power law would lie almost along the power law curve and would not alter or move the overall pattern if they were displayed.

The overall close adherence to the SM/PDG data, of the masses derived from a single equation and its rules, accounts systematicly for a basic regularity of the seemingly irregular progression of the lepton and quark/anti-quark masses. In this system, other relations would be coincidental or derivative.

FURTHER IMPLICATIONS—In such a view, the Table 1 cases of larger empirical mass uncertainties for SM particles with several options derived here might predict that nature may include mixtures of functionally similar particles with different masses. This should be testable. (See examples 2 and 3 of Appendix C.)

Also, the available options here appear sufficient in number and in numbers of components for category correlation with many special interaction characteristics such as charm, strangeness, flavor, spin, anti-particles, stability, lifetimes, the nuclear forces, electric field, etc. (Some initial examples of possible form and function association with number of components are listed in Appendix B.) The options would be especially adaptable if matched singlet and triplet options, with limitations, are included (as indicated by the non-SM low mass items of Table 1) in varied structural locations of natural forms due to number of components.

The matching application of the equation to the established SM top quark implies that the composite sub-structure power law of particle masses might be extended into the general proliferation of less frequently observed heavy particles. In addition, there are within the particle mass range noted here a number of unassigned, but systematicly regular, mass and charge quantal options which might apply to lighter particle proliferations. In general, this would imply the possibility of a very large number of potential rarely observed particles, thus correlating with, and tentatively accounting for, some of the previously observed or unconfirmed (Eidelman, et al., 2004) proliferation. (Some specific examples of such potential extensions are noted in Appendix C.)

As a final correlation, the high ratio graph in Figures 2A and 2B would indicate a very large increase in mass (as if from internal interaction energetics) with numbers of components under the sixth power law. Thus, in the heaviest quarks/anti-quarks most of the component interaction capability would be either engaged well within the assembly of components or shielded, with little of that capability interacting for mass gain externally between quarks/anti-quarks in the heavier hadrons, where that ratio approaches 1 in Figure 2A. Certainly, the light quarks/anti-quarks, with a necessarily higher ratio of external exposure of any sub-structure components from within the smaller component assembly, do make up the light hadrons most capable of the more energetic nuclear strong force interactions and greater stability (as in the proton.) The light electron/positron, with even less internal interaction mass gain, could have its six charges on the implied group surface (Appendix D.) for a greater ratio of exterior interactions. This implies for all particle interactions a quantized surface to volume ratio effect, as for a sphere, where $S/V = 3/r$. (Here "Volume" might also be taken to indicate scalable internal compartmentalization in some types of cases rather than large increases in particle volume or radius.) That would imply that such external interactions of particles may be largely geometrically quantized attraction, repulsion, twisting, or combinations of these, between configurations of sub-structural components with more or less surface exposure of many variably polarized, fully neutral pairs plus balanced numbers of partially neutralized though oppositely charged pairs, both with very short range net forces, and/or with limited numbers near the particle surface of unneutralized charge pairs with longer range force fields.

CONCLUSIONS—A simple, independently observed, equation correlates the composite masses of the SM hadron particles with the PDG empirical masses of their quark and anti-quark sub-structures. It can also be applied to the more elementary LQ class of SM quarks, anti-quarks, leptons, including neutrinos, and anti-leptons, to estimate their PDG empirical masses and charges as composite structures of microquanta of 1/6 fractionally charged sub-particles with informative accuracy. This is the simplest basis for the generalized structure of all these particles. The regularity of particle mass derivations arises here from a sixth power law for the variable number of quantized components. Departures from a strict power law come systematicly from quantally matching both conserved charge and mass of particles. Tying in the top quark extends a regular systematics of mass and charge into the proliferation of particles. This simple numerical link to the data of empiricly observed SM particles for estimates of sub-structural elements, and for a regular power law of masses, provides a departure point for re-examination of the uncertain masses of quarks, neutrino oscillations, and related phenomena. There are further implications of potential interest including relevant Appendices A through D, with some specific examples of broader mass regularities estimated among all levels of sub-atomic particles in Appendix C. The general mass regularity numericly exemplified there, from series of higher level heavy hadrons to the lightest neutrinos, is entirely dependent on a basis of lower level regularity of masses laid in the LQ particles from microquantal components by the systematic mass sub-structure power law identified in this research note.

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Appendix A—Neutrino mass ratios.

General—Because of the large uncertainties in all prior attempts to measure neutrino masses directly, the masses of the three (indirectly) observed "light" neutrinos are usually defined empiricly as upper mass limits in a "normal hierarchic order." So does the authoritative PDG (Eidelman et al., 2004), cited here for data on SM and non-SM particles. The PDG as a whole relies on and accredits a much higher range of upper limit empirical mass findings than do the included Notes of some of its members cited in the introduction of this paper or many analyses of the cosmic astrophysicists cited below. Some of these only state mass limits for the sum of all the possible mass states (as in Table A1.) Many of the physicists cited in Table A1 have found grounds for intermediate upper mass limits. There are, then, three distinctive ranges of possible mass values for the three observed neutrinos involved in theoretical and empirical research (as well as the SM possibility that all neutrinos have no mass.) There are also the previously cited inabilities to exclude a fourth (or more) kind of non-SM light neutrino. (Most of the recent empirical data is in terms of mass differences squared as the available approach to mass determinations. The mass options in this research note did not arise in that directional way, and are not necessarily suitable for comparison by reversing that kind of non-linear process.)

Likewise, researchers involved with high mass limits for the light neutrinos usually imply mass ratios between the neutrinos involving orders of magnitude. Those finding the lowest mass limits usually find ratios approaching 1, with the stated or unstated implication of degenerate non-distinguishability of the three observed types. Again, others find intermediate mass ratio distinctions, also more often implied than stated.

Other attempts have been made to generalize a resolution of the situation by finding mass ratios to be more significant than the exact mass values, or to use inferred ratios to find more specific values, or to find neutrino mass ratios by correlation with the ratios of masses of other LQ particles. From that prior work, relative mass ratio ranges may be useful in considering various approaches to neutrinos and their masses.

Specific—In the normal hierarchy, the mass of the lightest neutrino is analyzed as being associated with electron interactions; it is designated for the columns of Table A1 as m_1. The next higher mass in the table, m_2, is associated with muon interactions. The highest mass of the light neutrinos, m_3, is assigned to the tau neutrino, named for observations associated with interactions of the heaviest electron-like particle, the tau. (The masses may also be designated by the Greek letter subscript ν (nu) for neutrino with a second letter for the particle type in further subscript where that is not too small.) Also, in Table A1 for this appendix, subscripts such as t and c indicate the top quark and the charm quark. The most common ratio (M in Table A1) is that of m_2 to m_1, or that of m_3 to m_2 (N here-in.) Effective ratios of upper mass limits may be listed even though not discussed as ratios in many citations. Many discussions stated in ratios do not use the simple M and N ratios, but other forms. All masses here-in are in rounded eV (if unstated.) The citation list of Table A.1. is typical of each range and type rather than exhaustive.

In Table A1, the PDG report is well documented at its high range mass limits. So are the analyses of solar and atmospheric experiments and the cosmic theorists' work at their intermediate and very low range mass limits. On separately done (not shown) log plots against the masses of the related electron-like particles, the neutrino mass limit slope in the PDG high range is very close to 1.6. At the cosmic low range of near degeneracy, the slope is very near zero. Perhaps that is also a useful way to look at the M and N ratios.

TABLE A1. Typical neutrino masses and implied or stated mass ratios.

Source	Type	m_1 eV	m_2 eV	m_3 eV	M	N	Other ratios, etc.
PDG upper limits, cited	empiric	< 3	<0.19M	<18.2M	63.3k	95.79	
Options vs PDG here-in	"	2.43	0.17M	multiple	70.0k	11.24 to 106.7	
Vogel and Piepke, 2004	analytic	<2.8	<0.17M	<18.2M	60.7k	107.06	Notes cosmic sum<0.7.
Olive, 2004	cosmic						Sum<24
Barger et al., 2002	cos/analyt						Sum<4.4
Rodejohann, 2002	theo/analyt	<2.2					Number of neutrinos not known
King, 2003	theo/analyt	<6–20					Sum<28, or <6.6, or <3
Hannestad, 2003	cosmic						Sum<1.5–3; 2 to 7 types
Elgaroy and Lahav, 2003	cosmic						Sum<1.1–5.5; degenerate
Xing, 2002	cos/theo			<1, >0.1			Sum=1.5, nearly degenerate
Kayser, 2004	analytic	<0.3–1.0		<0.23, >36m			Sum<0.71, 4+ types question
Joshipura, 1995	theory					$=m_t/m_c$	$(m_3-m_1) / (m_2-m_1) = (m_t-m_u)/(m_c-m_u)$
Babu and Barr, 2000	theory				$=(16)^2 m_c/m_u$;	$=m_t/16m_c$	quark ref. and N=24.3
Lipmanov, 2003	analytic		0.09–0.34		$=\exp(2^{0.5}/900)$	$=\exp(2^{0.5}/30)$	$2^{0.5}(M-1) = (N-1)^2$
Ross, 2003	theory	3m or 1.0					degenerate
Kaus and Meshkov, 2004	theory	0–2.6m	8.3m	52m		6.25	milli-eV, nearly degenerate
Chacko et al., 2004	cos/theo	2m	8m	50m	4	6.25	milli-eV; 4 types, " "
Albright, 2004	cos/theo	2.8m	8.8m	51m	3.1428	5.795	milli-eV; nearly degenerate
Ellis et al., 2002	theo/analyt	0.01m-1					10 micro-eV to 1 eV
Gouvea and Valle, 2001	theory	<3					Sum < 30 What is wrong with neutrino masses?

However, in the case of the neutrino mass options observed here-in, the M and N ratios themselves are too far removed from their separate mass sources not to be obscured, and they are not used in the body of this note. Though the options are listed as electron, muon, or tau related, that is because of the conventional breaks in the PDG mass limits taken as reference. This system cannot determine those assignments from the composite sub-structure equation itself. Neutrino degeneracy is also not a derivable factor in this system. Thus, every neutral mass option derived from the equation here-in could be assigned in association with any charged lepton. The lower neutral options in Table 1 of the body of this paper could be assigned to muon and tau associations at an intermediate plot slope in a log plot or at near zero slope. So could any fractional eV mass options that may be derived from extending additional powers of the 1/3 neutral gain ratio into the fractional region. Even the less frequently seen inverted mass hierarchy could be assigned the quantized options currently found over the light neutrino range.

The overall situation of conflicting neutrino mass and mass ratio findings shown in Table A1, with ramifications throughout particle physics, has other composite sub-structure aspects which can be explored more clearly after Example 2 of Appendix C on proliferation of particles leads into the more complex Example 3, with its direct application in Example 4. That final example deals with possible mechanisms of neutrino mass oscillation between kinds of neutrinos and their differences in mass (expressed in the ratios.) Those mechanisms arise directly from the composite structure equation and its quantized organization of systematic regularity in particle mass options. In the result of Example 4 there are more definite implications about the neutrino mass ratios and their three conflicting mass ranges.

APPENDIX B—Examples of particle properties that may correlate with sub-structure component numbers.

The symmetry of anti-particles would be a natural starting restriction for such correlations. Distant static electric field options should be straight-forward. Charm, strangeness, and similar distinctions in quarks vary from the up and down quark qualities in cyclic step with their separations into particle groups by multiples of the number of electron components, as listed in Table 1 of the main body of this note. The up and down quarks are within the first multiple below 12 components. The strange quark is within the second multiple below 18. The charm quark advances within the next cycle divided at 24. The bottom quark takes two multiples to 30 and 36. Two multiples are passed over to 48 before the top quark occupies the third below 54. (If another quark is found, which is doubtful from mass/stability trends, this cycle might indicate that it may appear with a mass derivable from about 24 more components, near 78.) This observable cyclic mass relation between 6 component multiples in the present system appears to have some prospective connection with changes of other quark properties and could potentially be used to categorize these particles either generally, or perhaps in assemblages of cubic face-centered structural forms, if that should prove to correlate informatively with other factors. The muon and tau particles vary quantally in multiples of 8 components and could not participate there (which might lead to a further distinction from electrons). But they might be found to imply cubic vertex oriented structural forms, for instance, as in crystallography. (Or possibly it will be found that a cycle based on 8 components structurally constrains the properties of all LQ particles more massive than the electron.) Spherical forms, which in particular cases might be consistent with either of those two forms (especially if seen as truncated spheres), are also mentioned in other parts of this research note. This general type of potential geometric linkage between particle functions and views of form and number of components is an inherent and possibly informative consequence of the mass and number systematics observed here. Physical symmetry implications of the different spin quantum numbers might be more difficult to correlate with forms arising inherently from number of components. The single case of the electron neutrino appears straight-forward in spin from the linear simplicity of a two part form, but useful selection between the possible spin modes will probably require correlation with more complex cases with larger numbers of components. Particle stability and lifetimes might be quite difficult until the options in many other characteristics are worked out. Etc. The numbers of components here are sufficient and observably cyclic with variation of particle function that they may be useful as discriminating markers between categories of particles in general or in further structural systematics of linkage between function and form inherently due to number, beyond the present scope. Interrelation of component numbers with a deeper layer of quantum probability zones may eventually be the only overall workable outcome. Either of these results would be beyond the current SM, but not necessarily contradictory to it (possibly consistent with it.)

Appendix C—Some specific examples of applying the composite power law among the "proliferation of particles" (including a conceptual mechanism for "oscillation" of neutrino masses near the PDG limits and below.)

General—As may be noted from Appendix A, the proliferation of particles might include not only those less well observed and established cases among the hadron composites of quarks, but also the LQ neutrinos, with such widely varying upper mass limits from different citations, and the LQ quarks, with such wide PDG mass uncertainties listed in Table 1, that an inference may be drawn of possible multiple members in each sub-type. As shown in Table l of the body of this research note, the composite power law does quantally indicate such multiple LQ options (not all of which are listed in the table's scope, though more are included here.) In fact, the multiple options in the table for quarks are necessary to account systematicly for the regular progression of multiple proliferations in the PDG hadron mass examples explored here. The systematic numeric regularity of fit to the empirical PDG data, particularly in Examples 2 and 3, may give some support to the possibility of two mass options for each type of SM quark.

Similarly, the Table 1 options in both quark masses and tau neutrino masses provide jointly a systematic mechanism for mass oscillation of the various neutrinos near the PDG mass limits and below them. (By application of the implied *i*th power of the 1/3 neutral mass U rule, options for secondary fragments in oscillation may be systematicly extended to the recent extremely low, cosmic mass limits for neutrinos noted in Appendix 1. This type of extension is exemplified by the E case of the electron neutrino in the main body of the note.)

Thus there are three methods of applying the composite structure power law equations to uncertain and proliferative particle observations. First, calculate mass estimates with equation (6) and the applicable rules as in Example 1 to check whether the data fit a systematic series option in the LQ particles or an extrapolation from prior trends. Second, determine by the procedures of Examples 2 and 3 whether the particle fits a PDG recognized (or an unrecognized) regular mass sequence of related hadrons made up of the quarks/anti-quarks. Third, those techniques may be extended as in Example 4 to explore some of the possible kinds of collision interactions involving LQ and hadron particles with uncertain particle results, as might occur in neutrino oscillations.

Example 1—*Very rare and incomplete observations of isolated and uncertain particles*—This includes cases which the PDG has not accepted for either accredited Summary Listings or acknowledged status, but has not rejected from tertiary lists of uncertain observations of particles. In the PDG listings for Free Quark Searches (Eidelman et al., 2004), in 1980 and 1981 twelve particle observations were reported (though only nine qualified for secondary listing as not relied upon, though listed) with charge +1 and masses approximately 4.5 times the mass of the proton. That would be about 4.222 GeV. This is at the middle of the PDG mass range of 4.1 to 4.4 GeV for the bottom quark/anti-quark with ± 1/3 charge (for which Table l shows the two available quantal options of this note.) With the charge of +1 there is also a quantal option of 6++, 3—, 5+— pairs at the same 4.0218 GeV mass estimate as the lower bottom quark/anti-quark mass in the table.

The +1 charge and mass combination does not appear currently to coincide with any LQ particle sequence. Neither does it coincide with any hadron mass sequence currently explored with the method of the next examples. Until such a systematic niche is worked out in the SM/PDG data, this method can only hold the particle information suspended in file, as the PDG does. That kind of suspended question of mass regularity did not occur in the next example with the Omega minus (2470) particle, which is given a name by the PDG, but not included in the fully accredited Summary Listings. (Eidelman et al, 2004.)

Example 2—*A short serial sequence of hadron particles with a member still subject to question*—The Omega minus particles have four PDG members made of three strange quarks (*sss*, with no anti-quarks) in an apparent sequence of PDG mass listings below. (The charge of –1 is not in question here.) In the present system the systematic regularity of the four particle masses, and their limitation to four cases, comes from the four (and exactly four) possible combinations of the two strange quark mass estimates from Table 1 in any three *s* particles.

(Note that in the next example, more particle cases may also arise in clusters around such

TABLE C1 (Ex.2). Procedure steps for Example 2 in calculation of mass estimates for series of particles

Particle	PDG Mass MeV	Quarks	$\sum_{0,1,2,3}$ MeV	$r_{0,1,2,3}$	$w_{0,1,2,3}$	$y_{0,1,2,3}$	$m_{1,2,3}$ MeV	Deviation
Ω^-	1672.45 ± 0.29	3 s_1	247.401	1	1	1.739498	Given	NA
$\Omega(2250)^-$	2252 ± 9	$2s_1$+$1s_2$	272.124	1.09993088	0.7808	1.925138704	2255.75	None
$\Omega(2380)^-$	approx. 2380 (± ?)	$1s_1$+$2s_2$	296.847	1.199861763	1.002	1.89098301	2370.07	? (< 0.42%)
$\Omega(2470)^-$	2474 ± 12	$3s_2$	321.57	1.299792644	0.9200	1.856538146	2472.12	None

a combination, presumably, from internal arrangements of the members of the possible combinations with differing masses, etc. But that apparently has not yet been observed reliably in this Ω^- series. In other series, there may also be other forms of clustering of particles around such a combination of quark masses from other types of internal arrangement than are pointed out in Example 3 with its added informative step of increase in complexity.)

Proceed with Example 2 as follows: Call the two estimates of mass in Table 1 for the strange quark $s_1 = 82.467$ MeV, and $s_2 = 107.19$ MeV. Use the lightest and most accurately known Ω^- particle as the base reference, p_0. Assign it 3 each of the lighter s_1 quark mass and sum them. Substitute this and the accurately known PDG mass of p_0 in the original equation (1) and solve for y_0. (Note that the original y and R for this particle in Fig. 1A through 1D, were figured using a generalized average of the PDG s quark mass limits. This example uses the specific lightest value estimated here-in.) Check the calculated y_0 in equation (1) to regain the stated PDG particle mass m_0 with no more than minor rounding errors. Its accuracy is essential, as it (and other p_0 data) is to be used to calculate the proper $y_{1,2,3}$ and estimated $m_{1,2,3}$ for the remaining particles of the series, provided that there is an actual systematic regularity of those masses based on the two-valued quark mass. The only other data required are the sums of the other three combinations of the two s quark mass values as assigned in matched ascending order to the other three particles. Calculate the ratios of those component sums to the sum for p_0 as $r = \sum_{1,2,3} / \sum_0$. Apply equations (C1and either C2 or C3) below and equation (1) to calculate $w_{1,2,3}$, $y_{1,2,3}$, and the resultant mass estimates, $m_{1,2,3}$ for Table C1(Ex.2). (The PDG masses for the three larger particles are used only to find a resulting deviation of the estimates from the PDG listings.)

Note at the mid point of working up the table, in the ratio of the sum of component masses for each particle to the sum for the reference particle, that this ratio r progresses in even steps of very close to 0.10. This is controlled by the incremental difference in quark masses, and it in turn controls the cyclic phase (or sign actually) of the cosine correction factor in equation (C2). (With this early observation in the r column the final result of numeric regularity can be anticipated, provided that the empirical data matches it.) A graph of the ratios of the four resultant particle masses to m_0 versus the ratio of sums is a very regular curve. (Fig. C1.) Note that all three mass estimates do approximate the PDG limits, showing that $\Omega(2470)^-$ is a valid member of the systematicly regular series in the present general power law system of mass and charge correlations.

For this calculation the basic equation (from the body of this note) is equation (1), in which the number of s components here is 3, and for each of the three particles to be estimated in mass

$$y_{1,2,3} = r_{1,2,3}^2 y_0 (2 - r_{1,2,3}{}^{wr}), \quad \text{where the exponent } r = r_{1,2,3} \text{ also,} \tag{C1}$$

$$\text{and} \quad w_{1,2,3} = z_{1,2,3} + 0.057 \cos[F\pi(r_{1,2,3} - 1)] \tag{C2}$$

$$\text{where} \quad F = 1 \Big/ \sum (r_{n+1} - r_n)/n = 10, \tag{C2a}$$

for the inverse of the average difference between the r series in the table, and z is the w locus of an iteratively fitted circle in the rw plane from a preliminary estimate of the three w points with a cosine correction for generality of use in cyclicly spaced data such as this. Thus:

$$z_{1,2,3} = +[R_c{}^2 - (r_{1,2,3} - m)^2]^{0.5} + k, \tag{C2b}$$

where the radius of the circle $R_c = 0.24938273$, and the center coordinates $m = 1.32402639$, $k =$

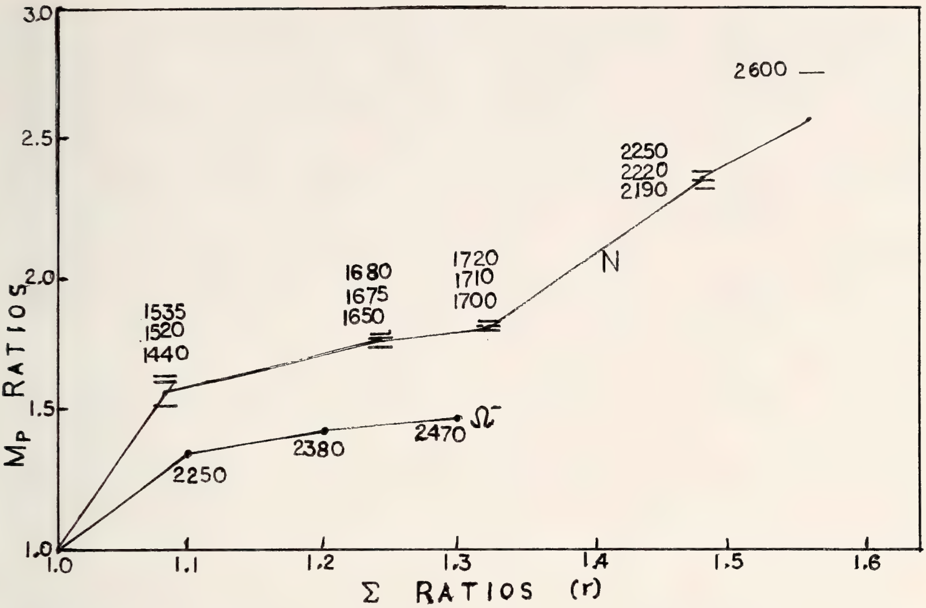

FIG. C1. Ratios of particle to reference masses vs ratios ($r_{0,1,2,3..}$) of sums of component masses to reference sum for Example 2 (four Omega minus particles) and Example 3 (fourteen neutral Nucleons) of Appendix C.

0.728804255. Since there are only three points, the circle gives an exact fit for w with the general cosine correction sign of ± 1.

This sequence of calculations establishes that the masses of this series are numericly quite regular, subject to any refinement of the PDG approximate value on $\Omega(2380)^-$. (The general cosine correction term is redundant in this case, as the circle could alternatively be iteratively fitted directly to the w estimates. However, the cyclic cosine is necessary in other alternative methods, including the next method, presumably for informative reasons, and may reduce the number of base curve iterations.)

A more broadly applicable exponential impulse curve for any number of particles in a mass series matches the real trend of the data in this case and in the longer series currently explored. This curve can be fitted iteratively with an estimated cosine correction to the initial run on w. After four iterations it is not quite as accurate in this example. This equation replaces (C2) for general use with more than three particles to be estimated in mass from the base particle.

$$w_{1,2,3} = \frac{ex}{2\, e^x} + 0.5 - 0.025 + 0.025 \cos[F\pi(r-1)], \tag{C3}$$

$$\text{where} \quad x = \frac{20\ (r - 1.05)}{3} - 0.025 \tag{C4}$$

and F is as in equation (C2a). This combined exponent and coefficient x compresses the general impulse curve and locates its peak near 1.0 in the r dimension of the rw plane. The 1/2 factor and 0.5 term (C3) compress the impulse curve and locate its peak at 1.0 in the w dimension. The other small terms adjust the curve slightly. The cosine term makes a cyclic correction with the particle-to-particle steps in r as before. This equation set would be more accurate in this example case with slightly more compression in the impulse curve at a 22/3 factor in x, possibly an additional cyclic term adjusted by inspection at a lower rate in r, and a re-iteration of the translation terms. However, the compression shown is at a current general-purpose level. (A graphic plot against r of estimated w values and a transparent overlay of this impulse curve may be found useful in guiding the convergence of iteration adjustments to determine the presence or absence of numeric regularity.) The three results currently obtained are in ascending order of mass in

TABLE C2 (Ex.3). Components. sums, ratios, and differences for the proton and neutron series.

	Series *p (uud)*	$\sum$, MeV	*r,*	Differences	Series *n (udd)*	$\sum$, MeV	*r,*	Differences
0.	*aav*	8.939	1	NA	*avv*	12.136	1	NA
1.	*abv*	9.896	1.10706	0.11	*bvv*	13.093	1.078856295	0.08
2.	*bbv*	10.853	1.21412	0.11		(SKIPS 14)	(SKIPS 1.16)	(0.08?)
		(NO SKIPS)			*avz*	15.057	1.24068886	0.08
3.	*aaz*	11.860	1.32677	0.11	*bvz*	16.014	1.319545155	0.08
4.	*abz*	12.817	1.43383	0.11		(SKIPS 17)	(SKIPS 1.40)	(0.08?)
		(NO SKIPS)			*azz*	17.978	1.481377719	0.08
5.	*bbz*	13.774	1.540888	0.11	*bzz*	18.935	1.560234015	0.08

GeV: 2253.708, 2373.900, and 2516.48. The first two are within the PDG tolerance of Table C1; the last is 1.72% high, which is probably adequate in this case (without further iterative adjustments) to agree with the first finding of systematic numeric regularity of masses, but might leave questions otherwise.

The mass regularity observed here within the higher level hadrons by this systematic view is entirely dependent on the lower level regularity of quark masses in the LQ particles under the sub-structure power law with Elements 1, 2, and 3. Example 3 is a more complex use of the same sequence of equations (1, C1, C3, C4.)

EXAMPLE 3—*Exploring a long hadron mass series, with clusters and gaps, for hidden regularity*—The most basic and numerous SM baryons in all of nature, as we know it (*e.g.*, Treiman, 1999), are the proton, with +1 charge from two up quarks and a down quark (*uud*, no anti-quarks), and the somewhat heavier neutron, with neutral 0 charge from two down quarks and an up quark (*udd*, also no anti-quarks.) Together, these two baryon particles make up the SM heavy nuclei of the typical relatively long-lasting (not all truly stable) atoms of nature that are heavier than hydrogen (with its one proton and no neutrons.)

In the cited PDG listings the proton and neutron are grouped in an apparent single series called Nucleons together with 13 other observed Nucleon N baryons, for which no charge status is given. It appears to be proper to class them together for reasons including the observation that all seem to share the ability to participate in an atomic nucleus from time to time. The 13 less frequent N particles in the formal listings appear to be viewed as excited resonance states with heavier mass (Hoehler and Workman, 2004), in association with 7 more questionable N observations that are not formally listed, and also with a large PDG group of Delta particles, a very few of which are listed with stated positive or neutral charges. (There is no definite PDG rejection or recognition of a Delta series connection with nuclei, as there is with the N Nucleons.) With two estimated mass values for each of two involved quarks, and with two different quark compositions with different + and 0 charges, there will be a more complex situation than in Example 2.

To proceed with Example 3 essentially as before: Call the two rounded mass estimates from Table 1 for the up quark $a = 1.914$ MeV and $b = 2.871$ MeV. Call the two specific estimates for the down quark $v = 5.111$ MeV and $z = 8.032$ Mev. Since there are two formulas *uud* and *udd* with different charges + and 0 for the proton p and the neutron n, there should be two separate series, not one. There will be two base references at the lightest and most accurately known PDG listed mass for each type, $p_0 = 938.272029$ MeV and $n_0 = 939.565360$ MeV with very small uncertainties. Therefore, assign the possible quark mass combinations to each of them in ascending mass order. Sum each combination. Find r ratios for these sums to the reference sum $\sum_{0,1,2..} / \sum_0$ in each case. Then note the ratio differences between succeeding ratios at each ascending step in the sequence. Compare these mid-point results in Table C 2 (Ex.3.)

From this table, the proton based series seems very much like the mid-point pattern in Example 2. The series can presumably be processed in the same way as Example 2 with small adjustments. That is, it can if a series of relatable observations of +1 charged, apparent *uud* class particles is available for exploration, as noted later.

The neutron based series appears to require new considerations because of the gaps in regularity options. In addition, there are only 5 options above the neutron reference mass, and there are 13 PDG accredited listings of N series particles heavier than the neutron. These include a few that are considered only very likely existent in the PDG Note on N and Delta Resonances (Hoehler and Workman, 2004.)

Reviewing the 13 PDG mass listings beyond the neutron, they appear to fall into 4 clusters of 3 each with 1 extra particle at a considerable mass separation. (See values in calculations below.) Arbitrarily assigning these 5 empirical particle clusters to the 5 mid-point sum ratios of the n series in Table C 2 (Ex.3), the r for each N particle can then be plotted with a short dash at its ratio of PDG mass to the neutron mass on the same Fig. C1. as Example 2. The comparative appearance of the tentative cluster groups is regular and comparable to the Omega minus curve, though the gaps between clusters are prominent.

In the calculations, the significant difference from Example 2 is that, by inspection of preliminary estimates, the cosine correction (on the impulse curve for w in Equation C3) must oscillate primarily through the missing gap values where the slope of the curve changes. This is accomplished by setting F at $1/0.28 = 3.57143$. The adjustable terms are balanced iteratively as before.

After completing the 5 sets of calculations as in Example 2, for Cluster 1 of *N(1440), N(1520),* and *N(1535),* the estimated cluster center mass is 1477.79 MeV. For Cluster 2 of *N(1650), N(1675),* and *N(1680),* the estimated cluster center mass is 1664.65 MeV. For Cluster 3 of *N(1700), N(1710), and N(1720),* the estimated cluster center mass is 1715.45 MeV. For Cluster 4 of *N(2190), N(2220),* and *N(2250),* the estimated cluster center mass is 2239.88 MeV. These 4 appear quite systematicly regular, especially when the estimated cluster center value ratios to the neutron value are also plotted in Fig. C1 and connected in a regular (unsmoothed) curve.

Due to the fact that the main bends in the curve occur at the longer gaps between clusters, the ratio curve at Cluster 4 definitely sets the trend of the slope on to a fifth cluster. For the putative Cluster 5 with a single particle member (one of those considered only very likely to exist), *N(2600),* its name is its PDG approximate mass (with uncertainty of –50, +150) in MeV. The estimated cluster center mass is 2419.66 MeV. Plotted as ratios in Fig. C1, the deviation is about two times the total range spread of Cluster 1, which is the most scattered of the other complete clusters. It is unlikely that additional iterations or adjustments would reduce this deviation significantly while retaining the internal match to the other clusters. However, there is an implication that either additional cluster members may be observed with a greater spread to include the estimate, the particle may be empiricly downgraded by PDG to fairly likely to exist or changed in listed mass, or a significantly different internal effect may be found elsewhere to differentiate this from the other clusters of the series. Pending such possible eventualities, this particular mass of the curve in Fig. C1 is regular only to an indicative degree.

There is also an implication, of form due to number in the first four clusters, that the three separate particles in each of them may be due to whether the up quark is internally located between the two heavier down quarks, or on the exterior side of some other feature such as the direction of the PDG spin vector, or on the opposite side from the feature. (A similar mass splitting may eventually be observed due to formation possibilities with smaller quark mass differences in the Omega minus particles of Example 2. Finer measurements might thus test this implication.) In addition, since the presumably neutral N particles all appear to be generally in a numericly regular mass series in *udd* based on the neutron, there may be other *uud* particles with +1 charge in other mass sequences (such as the Delta resonance listings of the PDG cited earlier) to explore in connection with the proton series of quark mass options. (However, the exceptional PDG listed stability of the proton might imply that suitable particle observations may be limited.)

Currently, the 6 N neutral combinations of the quarks are found numericly regular here, and apparently do compose the particles accredited by the PDG to participate in the nuclei of atomic matter (at some rate or probability determined elsewhere.) As such, they have a different optional possibility to explore in Example 4. This should shed more light on Appendix A.

Once again, the mass regularity observed here within the higher level hadrons by this systematic view is entirely dependent on the lower level regularity of quark masses in the LQ particles under the sub-structure power law with Elements 1, 2, and 3.

EXAMPLE 4—*A thought experiment sample of possible neutrino "mass oscillation" mechanisms arising from composite options applied to the cited empirical proliferation of possible neutrino masses*—It follows directly from the observations of Example 3 in this appendix and the citations of Appendix A, that the various PDG N nucleons and neutrino mass limits, plus the multiple tau neutrino options of this note, might jointly provide a numericly regular and systematic description of inelastic collisions of particles, including neutrinos. That leads on directly to the various questions surrounding the arguably unexplained (*e.g.,* Branco et al., 2004; Ellis et al., 2002, Gouvea and Valle, 2001) and problematicly observed "mass oscillations" between the three kinds of light neutrinos. Different kinds of observable effects and related theory have categorized these neutrinos to the three separate leptonic types, whether coming from the sun (solar), cosmic rays (atmospheric), reactors and purified samples of unstable atoms or particle colliders (experimental), supernovae (cosmic), etc. (*e.g.*, the previously cited PDG Notes and their references: Groom, 2004; Hoehler and Workman, 2004; Kayser, 2004; Olive, 2004; Vogel and Piepke, 2004: as well as Nakamura, 2004; and numerous journal reports, including: Albright, 2004; Barger et al., 2002; Caldwell and Mohapatra, 1993; Chacko et al., 2004; Elgaroy and Lahav, 2003; and Rodejohann, 2002.)

The principal empirical anomaly for all neutrino particle concepts that are not totally degenerate between the three accepted types, is that a very light electron-related neutrino, after entering an uncertain "oscillation" process, emerges as another type of neutrino with a mass that is either somewhat heavier or orders-of-magnitude heavier (especially if near the PDG mass limits.) Similar actions may occur with the muon neutrino, or a tau/muon neutrino may reverse the oscillation process, etc. While rarely stated, this is largely or entirely beyond the SM.

Due to the very low rate of observation of neutrino collision effects in detectors compared to the very large expected numbers of the particles passing through detectors in many of the cited reports, it is highly unlikely that neutrinos newly arising from collisions in detectors would be observed by further collisions and traced to the first collision, except possibly in dense cosmic ray bursts. Consequently, any question of a lack of observations supporting the options noted here is given no weight. These options are probably not directly observable. They should be largely distinct from the observed PDG particle decay modes. This example is a simplified schematic observation, within the composite system, of some possible component pair outcome options within the debris of inelastic collisions. No attempt is made at relative probabilities of outcomes. The usual convention of referring to the neutrinos as associated with one of the three charged leptons is continued as more convenient in terms of possible original sources and mass ranges. However, in accordance with the trend toward recognition of degeneracy and the non-standard interaction possibilities cited next, it is not assumed that the three labeled types of neutrinos are completely unable to interact with any other particles than their namesakes. That is not the simplest assumption.

It is noted here that the neutrino oscillation process is now regarded as requiring the presence of "matter" rather than occurring in a theoretical vacuum. (*e.g.* Nakamura, 2004.) The process may involve anomalies and non-standard interactions in addition to the requirement for matter (Valle, 2003a,b; Catani et al., 2004.) It may also include regeneration of neutrino flux in passage through earth (Lunardini and Smirnov, 2003.)

The presence of matter provides for very large numbers of N nucleons along a neutrino's trajectory, whether within the sun or a supernova, within the earth's mantle, or in a few hundred kilometers of a chord of the earth's bulge over the horizon, or even within the earth's atmosphere. (It is unimportant for the purposes of this example that the neutral Ns other than the neutron may be present only in very low proportions. They have been observed; therefore, they may be present and do represent an interaction option. In the Avogadro's number class of atomic nuclear representation per mole of matter, a very small probability or percentage presence is not necessarily negligible, possibly not even in the fairly hard vacuum of typical galactic space. It should be presumable that there is some representation in space of neutral Nucleons (at least of neutrons) in deuterons and alpha particles from helium nuclei, if not from more massive products of stellar explosions, such as carbon, oxygen, etc. For these purposes, hydrogen may not qualify as matter in the same way as any heavier atom with neutrons in the nucleus.)

It is also notable that of all the nucleons cited by the PDG (Eidelman et al., 2004) only the proton is considered accreditably stable, while the neutron (if not the other neutral Ns for which no PDG statement is made) is relatively quite unstable if removed from the nuclear attachment to the proton. Therefore, the neutral N particles explored in Example 3 are considered in this limited example for options of disruption by neutrino impact. Since the quarks have never been reliably observed separately from the particles (per the PDG section on quark searches, Eidelman et al., 2004), they must be considered highly unstable for disruption if dislodged from an N nucleon. It is presumed in view of the other particle damages credited to neutrinos in observed detector collisions of the cited reports that at least a high energy tail of neutrino impact energy distribution may be sufficient for the disruptions indicated here, possibly from multiple impacts with intervening excitation. (The clustered PDG mass splittings of N particles noted in Example 3 may play a part there.) For reasons of empirical conservation of charge, it is presumed that previously formed charged mass pairs are not chaoticly broken at this hypothetical, widely available level of impact energy from within various kinds of stars in the solar and cosmic reports cited (as they might be in black holes perhaps.)

In a different consideration, loss of single neutrons or other neutral nucleons from atoms in typical purified detector matter, atmosphere, or earth, would at the most only initiate a relatively prolonged half-life decay process in the very small proportion of atoms involved. This would be highly unlikely to be detected or observed without considerable experimental effort for that purpose. If detected, there would be the question of excluding previously unstable atoms. (That is a possible test approach, however. Also, if that is observed, it could be a continuing low level source of radioactive atoms in atomic matter.)

Accordingly, electron neutrinos from Table 1 are taken (in a sample thought experiment) as impacting the *udd* quarks (from Table 1) of the neutral N nucleons (made of *ab* and *vz* quark masses) of Example 3 with sufficient energy that some portion of the nucleons are disrupted into smaller component pair groupings that can also be neutral in overall charge conservation and consequently difficult to observe, as with neutrinos generally. The reference particle (N_0) and the 5 numbered *udd* baryon particle clusters of Example 3 are 6 parallel input targets of the collisions. Any one of the typical three members of a cluster may be hit. Note that the N Clusters 1 and 2 from Example 3 (as input Cases 2 and 3 in this Example 4) have the same total pair compositions from their two-valued u (*ab*) and d (*vz*) quarks and, thus, the same conserved output options here. The same type of total pair composition equivalence is true of N Clusters 3 and 4 in present input Cases 4 and 5. Input Cases 1 (the reference neutron, N_0) and 6 (the N_5 truncated cluster) are each unique in pair make-up. Table C 3. (Ex.4) shows pair options of debris particle formation near the PDG neutrino mass limits in schematic form, using Greek and English letter names.

Each case in this table involves a total of 15 pairs of component quanta (1 pair in the electron neutrino and 14 in each type of Nucleon) which may separate by pairs in collision and reassemble by pairs as the various kinds and numbers of neutrinos shown in each optional case line. Doubling the options for the doubled cases (2 through 5), there appear to be at least 24 case outcome options (if not more), of which 16 might have an electron neutrino or two continue in company with heavier neutrinos, 12 might provide 1 to 3 muon neutrinos, and all 24 would provide 1 to 3 tau class neutrinos. These are completely balanced and neutral case options. (The electric charge bias toward neutral re-assembly options would be significant.)

In this power law system, the input at sufficient energy of a single electron neutrino into an assemblage of matter could thus result in an "oscillation" into the appearance of muon neutrinos and tau neutrinos. Aside from the statistical question of relative numbers and probability cross sections (discussed next in general terms), this possible mechanism is directly consistent with the PDG mass limit view of the empirical phenomenon of neutrino oscillation.

These options in the system are incomplete, however, without considering the additional options that collision debris might appear in the outcome in some of the low mass neutral options of Table 1 rather than in these more highly organized options. Or debris might appear in large numbers of the mass options from an ith power of the 1/3 ratio for neutral pairs, etc. And there is the possibility of triggering some of the more observable standard decay modes listed by the PDG. In addition, the heavier neutrinos might each within this system cause a similarly organized and systematicly regular "oscillation" progression in collision debris of the N nucleons in a reversion process back into the lighter neutrinos. Given time and increasing matter penetration, any total activity of this kind would arrive at a statistical balance between the competitively opposed trends. No complete probabilities or interaction cross sections, nor methods for their prediction, can be attempted within the scope of the stated power law equations alone. Comparative stability of the neutrino options would have an important effect. (If this is similar to the electron and proton stability vs size in type of particle, the smaller neutrinos would have a stability margin and always be at a significant percentage.) However, it does appear that such repetitive collision processes might possibly lead to each of the various types of cited observations of neutrinos from the different sources with

TABLE C3 (Ex.4). A sample schematic mechanism for systematicly regular neutrino mass oscillation.

		u or d quarks of one of the 6 neutral Nucleons, breaking that N and its quarks into component pairs.													
ν_e	HITS	Case 1. N_0		or Case 2. N_1		or Case 3. N_2			or Case 4. N_3			or Case 5 N_4		or Case 6. N_5	
INPUT:															
	Quarks	a	vv,	b	vv,	a	v	z,	b	v	z,	a	zz,	b	zz
	Pairs	2++	2−−	3++	2−−	2++	1−−	1++	3++	1−−	1++	2++	2++	3++	2++
1+−		2+−	8+−	1−−	8+−	2+−	4+−	2−−	1−−	4+−	2−−	2+−	4−−	1−−	4−−
								2+−			2+−		4+−		4+−
WITH REGROUPED OUTPUTS: in any of these neutrino options that the component pairs randomly re-assemble in (if all re-assemblies balance out neutrally again, as they might.)															
Neutrino options	ν_e	ν_μ			and 8 options in ν_τ (including the 4 tau neutrinos listed in Table 1)										
Pairs	1+−	3+−			1++	1++	2++	5+−	1++	2++	6+−	1++			
					1−−	1−−	2−−		1−−	2−−		1−−			
					1+−	2+−			3+−	1+−		4+−			
NUMBER OF EACH PER CASE:															
Case 1. options			1ea	2ea					1ea		2ea				
or				1ea										2ea	
or			1ea	3ea								1ea			
or			2ea	3ea				1ea							
Cases 2 or 3								1ea			1ea		1ea		
or											3ea				
or				2ea		1ea						1ea			
or			1ea	2ea	1ea							1ea			
or			1ea	2ea	1ea			1ea							
Cases 4 or 5.			1ea	2ea				2ea							
or			1ea					2ea					1ea		
or			1ea				1ea	1ea						1ea	
or			1ea					1ea			2ea				
Case 6.				1ea			1ea	2ea							
or			1ea					2ea						1ea	

some dependence on the amount, type, and status of matter penetrated, as well as on the mass and kinetic energy spectral sensitivities of the various kinds of detectors.

In result, a potential conceptual mechanism for neutrino mass oscillation is an inherent and regularly systematic implication of the composite sub-structural system and its mass relation equation. Furthermore, that mechanism implies a possibility that the confused empirical neutrino mass ratio situation outlined in Appendix A may have a real basis in approximately three significantly different ranges of neutrino masses (not excluding the possibility in some ranges of three kinds of resonant interaction with the three charged leptons) as a result of the debris of repeated neutrino collisions (with quasi-stable nucleons) while passing through extended amounts of matter, either in concentrations of matter or in attenuated matter distributed over galactic distances. That is, the PDG, the experimentalists, and the cosmic analysts conflictively cited may all three be correctly understanding different phases of a single neutrino mass systematics that arises from composite particle sub-structures.

This appendix schematicly outlines some systematicly regular examples of the further implications of the composite mass sub-structure power law system in conventionally elementary particles. In every example the broader regularity of masses seen in this system is entirely dependent on the lower level regularity of quark and neutrino masses in the LQ particles from their microquantal components under the sub-structure power law with Elements 1, 2, and 3.

Appendix D.—Contradictory evidence and questions on a radius, volume, or surface, for the electron.

The case of the electron in the series of surface-to-volume implications emphasizes the contradiction for that particle between any compartmentalization or component sub-structure and all of the prior experimental collision data on the particle's size and shape. That data indicates (as noted in typical summary on p. 17, Mac Gregor, 1992) that the electron is point-like (meaning of infinitesimal or zero size, of no physical volume, with no apparent sub-structure.) The same data also conflicts with the SM data that the electron has spin (Eidelman et al., 2004), which should come from rotation of an off-axis (and therefore non-point-like) mass, and has a magnetic moment, which should come from rotation of an off-axis electric charge (similarly non-point-like.) This data also conflicts with the various classical estimates that the electron must have a radius, several estimates of which are listed in the Physical Constants section of the PDG report (Eidelman et al., 2004.) In this inherent conflict of the present scientific knowledge, the electron is as uniquely peculiar as the electron neutrino. The implication that they both may have sub-structure of a generalized nature is unavoidably required to fit within the margin of error of the other relevant physics, or to find a basis in the conflicted evidence.

The conflict of the various views of the electron has been fought out inconclusively by various physicists on a continuing basis to recent times (*e.g.*, Rohrlich, 1982; Boyer, 1982; Rohrlich, 1997; Jimenez and Campos, 1999; Springford (ed.), 1997; Dowling (ed.), 1997); Hestenes and Weingartshofer (eds.), 1991; etc.) Possibly the most conclusive, and inclusive, study is a monograph based on a long series of published journal studies of the electron (Mac Gregor, 1992.) This report found that a finite, rigid, solid, massive, spherical body with a charge on its surface would give point-like deflections of typical impacting particles over the typical range of impact energies and match the other properties of the electron, when spinning at the relativistic limit. That finding would shift the burden of conflict (of any generalized sub-structure of the electron) with the point-like experimental impact data to the very specific future question (beyond the scope of this research note) of whether there might be some composite body in such a configuration, or one that might react to impact as if it were both a smooth, solid, spinning sphere and ideally rigid, and as if it had or approximated the other properties of the electron. Mac Gregor's monograph is taken to provide a basis for at least one initial approach, so that an implied surface of an unspecified volume of generalized components may be considered.

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HABITAT USE BY THE NONINDIGENOUS MEDITERRANEAN GECKO (*HEMIDACTYLUS TURCICUS*) IN NORTH CENTRAL FLORIDA

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Abstract: *We collected natural history data for the nonindigenous Mediterranean gecko (*Hemidactylus turcicus*) during three nocturnal surveys from summer 2001 through spring 2002 on the University of Florida campus in Gainesville, Florida. Adults consistently occurred at heights > 1m off the ground, whereas subadults usually occurred at heights ≤ 1m. Neither adults nor subadults demonstrated a tendency for social interaction. Adults occurred on both exposed and non-exposed wall surfaces, whereas subadults were generally found exposed. Adults chose substrates with higher mean temperatures than those chosen by subadults, and adults were typically located on warmer substrates in spring than in fall. The substrate temperature range for adults was smaller in spring than in fall, and larger than that for subadults in the fall.*

Key Words: Introduced species, gecko, *Hemidactylus turcicus*, urban ecology

Many nonindigenous species have become established in Florida (Simberloff, 1997). Among these is the Mediterranean gecko (*Hemidactylus turcicus*), which occurs naturally in the Middle East and Mediterranean region. Since being introduced in Florida in 1915, *H. turcicus* has become widely distributed throughout the southern United States (Stejneger, 1922; Conant and Collins, 1991; Nelson and Carey, 1993; Townsend and Krysko, 2003; Meshaka et al., 2004). Although a considerable amount of information has been compiled on *H. turcicus*, most pertains to reproduction, diet and distribution. Although these factors probably are linked to this gecko's ability to rapidly invade new sites, other natural history variables that have rarely been documented also may contribute to its colonization abilities. With this in mind, we analyzed patterns of habitat use between adults and subadults. Specifically, perch height, sociality, exposure, and selected surface temperature were studied in three distinct nocturnal field surveys.

The city of Gainesville, Florida, is an area where populations of *H. turcicus* occur in high density, allowing this gecko to be studied easily (King, 1959; Townsend and Krysko, 2003). Although the Indo-Pacific gecko (*Hemidactylus garnotii*) also occurs in Gainesville, these hemidactyline geckos rarely occupy the same habitats (Krysko, 2004). Thus, the Gainesville area offers an opportunity to study the natural history of *H. turcicus* in the absence of other species.

Materials And Methods—Our primary study area was the University of Florida campus located in Gainesville, Alachua County, Florida. The roughly 8 square kilometer campus has 1,251 buildings that provide approximately 1,734,510 gross square meters of building area (University of Florida, 2000). A secondary study site was the Gainesville Veterans Affairs Medical Hospital Center on the University of Florida campus, which consists of 38 buildings (US Department of Veterans Affairs, 2003). All fieldwork was conducted at these two sites. Buildings were constructed either of aluminum, brick, cement, wood or a combination of these materials. The majority of the buildings were less than 40 meters in length, and no more than 4 meters in height. Some type of vegetation surrounded roughly 80% of buildings, although the height and variety of the vegetation was inconsistent as a result of management techniques. The architectural features of the buildings were mainly windows, electrical boxes, wires and outlets, rainspouts, light fixtures, and eaves. It is important to note that more than 50% of the walls sampled did not possess a light fixture. Building location ranged between bright and loud high traffic areas to dark, solitary sites surrounded by thick vegetation. The study included three distinct nocturnal surveys, each being part of a larger habitat study where additional building/wall information can be found (Gomez-Zlatar, 2003).

SURVEY 1—During the initial survey in July and August 2001, we randomly sampled walls on 48 one-story buildings. To ensure gecko activity, each sampling session began two hours after sunset and lasted approximately two to three hours (King, 1959). We systematically sampled each wall by scanning it with a flashlight from top to bottom and left to right. Sampling occurred within one meter of the wall, and was conducted as quietly as possible. Each gecko was classified by eyesight as either an adult (> 40 mm SVL) or subadult (< 30 mm SVL) as established by a number of investigators (Rose and Barbour, 1968; Selcer, 1986). We excluded any geckos whose size could not be accurately established (< 10 individuals). We categorized the perch height of each gecko as 'low' if the gecko was ≤ 1m above ground, or 'high' if >1m.

SURVEY 2—We sampled 50 one-story walls on a weekly basis between September and December 2001. Walls were visited approximately two hours after sunset, and the same criteria were used to categorize adults and subadults. In addition to documenting perch height, we also quantified sociality, exposure, and selected surface temperature using the following methods:

(1) We defined sociality using these criteria: "alone" when a gecko had no other individual within a 50-cm radius, a "pair" when two geckos were within a 50-cm radius, and a "group" when three or more geckos were found together.
(2) Geckos were labeled 'exposed' when a portion of the trunk was visible, and "not exposed" when the entire trunk of a gecko's body was hidden behind a wall fixture.
(3) Using a Raytek Raynger ST model temperature gun, we recorded the substrate temperature at a spot within 5cm of the center of the gecko's body.

SURVEY 3—We sampled 160 one-story walls between the months of March and June 2002. We visited each wall twice using the same sampling regime and equipment as previously mentioned.

We used chi-square tests to compare perch height, sociality, and exposure between adults and subadults for all data from Survey 1 and Survey 2. We calculated means, standard deviations, and maximum and minimum values for all temperature data. We used a paired t-test to compare substrate temperature of adults with subadults. This test was limited to Survey 2.

Odds ratios and their 95% confidence intervals were calculated for perch height, sociality, and exposure for data from Survey 1 and Survey 2. The odds ratio, defined as the odds of success of an event in a 2x2 contingency table, represents a measure of association between two events (Agresti, 1996). The comparison between solitary and pair, and pair and group for Survey 2 required the use of an amended estimator (addition of 0.5 to each cell) to calculate the odds ratio as more than one cell of the contingency table was zero (Agresti, 1996). In cases where the 95% confidence interval contained the number one, the odds ratio was inconclusive since the number one signifies independence (Agresti, 1996).

RESULTS—*Survey 1*—We recorded 176 (131 adults, 45 subadults) gecko sightings. Of the adult observations, 97 (74%) occurred at a high height, and 34 (26%) at a low height (Table 1). With respect to subadults, 7 (16%) were located at a high height and 38 (84%) were located at a low height (Table 1). Perch height

TABLE 1. Perch height of adult and subadult *H. turcicus* arranged by survey. a = distribution of table chi-square per cell; b = p-value of cell using 1 degree of freedom.

	Observations	Observed frequency	Expected frequency	Cell chi-square	P-value
Perch Height of Adults					
Survey 1					
High	97	74.0%	77.4	4.96	0.026
Low	34	26.0%	53.6	7.16	0.007
Survey 2					
High	296	83.3%	247.1	9.66	0.002
Low	59	16.6%	107.9	22.13	< 0.0001
Survey 3					
High	170	71.7%	—	—	—
Low	67	28.3%	—	—	—
Perch Height of Subadults					
Survey 1					
High	7	15.6%	26.6	14.43	< 0.0001
Low	38	84.4%	18.4	20.85	< 0.0001
Survey 2					
High	105	47.5%	153.9	15.51	< 0.0001
Low	116	52.5%	67.1	35.55	< 0.0001
Survey 3					
High	—	—	—	—	—
Low	—	—	—	—	—

was not independent of gecko size groups ($\chi^2 = 47.4$, df = 1; p = <.0001). Chi-square values for individual cells showed that more adult geckos than expected under a hypothesis of independence were perched high, whereas fewer than expected were perched low (Table 1). Conversely, a smaller number of subadults than expected were found at a high perch height, and more subadults than expected were found at a low perch height (Table 1). The odds ratio was estimated to be 15.5 (6.3, 37.9), implying that the odds of observing an adult gecko located at a high perch height was 15.5 times greater than the odds of observing a subadult at a high perch height.

Survey 2—We used 576 (355 adults, 221 subadults) gecko observations to test for perch height preference. Of these, 296 (83.4%) adults were seen at a high position and 59 (16.6%) at a low position (Table 1). For subadults, 116 (52.5%) were located at a high height and 105 (47.5%) at a low height (Table 1). Once again, perch height was not independent of gecko age groups ($\chi^2 = 82.9$, df = 1; p = < .0001). As in Survey 1, cell chi-square values indicated that adult geckos appeared to choose high perches more often than expected under a hypothesis of independence (Table 1). Furthermore, subadults had the opposite pattern with fewer than expected perched high (Table 1). An odds ratio of 5.5 (3.8, 8.1) was

TABLE 2. Sociality of adult and subadult *H. turcicus* arranged by survey, a = distribution of table chi-square per cell; b = P-value of cell using 1 degrees of freedom.

	Observations	Observed frequency	Expected frequency	Cell chi-square	P-value
Sociality of Adults					
Survey 2					
Alone	287	80.9%	310.9	1.83	0.176
Pair	53	14.9%	34.8	9.5	0.063
Group	15	4.2%	9.3	3.45	0.002
Survey 3					
Alone	223	94.5%	—	—	—
Pair	13	5.5%	—	—	—
Group	0	0%	—	—	—
Sociality of Subadults					
Survey 2					
Alone	219	98.7%	189.1	3.01	0.083
Pair	3	1.40%	21.2	15.61	< 0.0001
Group	0	0%	5.7	5.67	0.017

calculated, indicating that the odds of an adult gecko occupying a high perch height was 5.5 times the odds of a subadults.

We recorded 577 (355 adults, 222 subadults) gecko observations in our analysis of sociality. Adult observations contained 287 (80.8%) solitary individuals and 53 (14.9%) individuals belonging to a pair (Table 2). The reason for the odd number of paired individuals was that one pair consisted of two geckos on adjacent but different walls; Thus, only the gecko on the study wall was counted. Finally, 15 (4.2%) individuals occurred in groups. Following a comparable trend, subadult observations resulted in 219 (98.7%) solitary counts and 3 (1.4%) pair counts (Table 2). No subadults were seen in groups. Sociality was not independent of gecko age ($\chi^2 = 39.1$, df = 1; p = < .0001). Specifically, cell chi-square values indicated fewer observations of solitary adults than expected and more observations of adults in pairs and in groups than expected (Table 2). Subadults displayed the opposite tendency, with more individuals than expected observed alone and fewer than expected observed in pairs and in groups (Table 2). When comparing solitary geckos and paired geckos, the odds ratio is estimated at 13.1 (4.0, 42.6). This implies that the odds of a subadult gecko being solitary is 13.1 times greater than the odds of an adult being solitary. An odds ratio of 23.0 (1.4, 384.6) is estimated when solitary individuals are compared with individuals in groups. Thus, the odds of a subadult being alone is 23.0 times the odds of an adult. Finally, when comparing pairs of geckos to groups of geckos, the odds ratio is estimated at 2.0 (0.1, 41.4). Since the confidence interval contains the number one, nothing can be concluded from the odds ratio in this case (Agresti, 1996).

We used 574 (351 adults, 223 subadults) gecko observations to examine exposure trends. Examination of these results revealed that 199 (56.7%) adults were exposed, and 152 (43.3%) were not exposed (Table 3). Of the subadult observations, we recorded 198 (88.8%) in the exposed group, which contrasts with the 25 (11.2%)

TABLE 3. Exposure of adult and subadult *H. turcicus* arranged by survey. a = distribution of table chi-square per cell; b = P-value of cell using 1 degree of freedom.

	Observations	Observed frequency	Expected frequency	Cell chi-square	P-value
Exposure of Adults					
Survey 2					
Exposed	199	56.7%	242.8	7.89	0.005
Not Exposed	152	43.3%	108.2	17.7	< 0.0001
Survey 3					
Exposed	178	75.0%	—	—	—
Not Exposed	59	25.0%	—	—	—
Exposure of Subadults					
Survey 2					
Exposed	198	88.8%	154.2	12.2	< 0.0001
Not Exposed	25	11.2%	68.8	27.85	< 0.0001

observations in the not exposed group (Table 3). Exposure was found to be dependent on gecko size ($\chi^2 = 65.9$, df = 1, p = < .0001). Cell chi-square values revealed that there were significantly more hidden adult geckos and exposed subadults than expected under a hypothesis of independence. The odds ratio was estimated at 6.1 (3.8, 9.6). Therefore, the odds of a subadult gecko being exposed was 6.1 times the odds of an adult being found exposed.

We recorded 576 temperature readings, with 352 taken from adults and 224 from subadults (Figure 1). The mean substrate temperature for adults was 23.2 °C

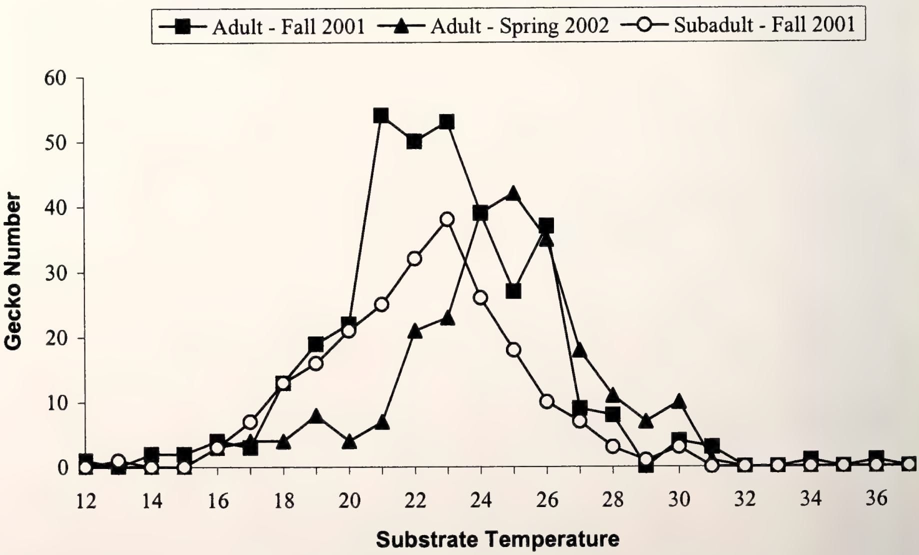

FIG. 1. Seasonal substrate temperature preferences for adult and subadult *H. turcicus*.

TABLE 4. Descriptive statistics for seasonal substrate temperature preference for adult and subadult *H. turcicus*.

	Average	Standard deviation	Maximum value	Minimum value
Survey 2				
Adult	23.2°C	3.05°C	36.3°C	12.7°C
Subadult	22.7°C	2.80°C	30.8°C	13.9°C
Survey 3				
Adult	24.9°C	2.94°C	31.5°C	16.4°C

(± 3.05), with a range of 12.7 – 36.3 °C. Likewise, the mean substrate temperature for subadults was 22.7 °C (± 2.80), with a range of 13.9 – 30.8 °C (Table 4). Substrate temperatures of adults and subadults were significantly different (t-test = 2.2, df = 574; p = 0.03).

Survey 3—This survey focused exclusively on adults, as most geckos were adult sized. We collected 237 perch height observations with 170 (71.7%) being high and 67 (28.3%) low (Table 1). For sociality, of 236 observations, 223 (94.5%) were alone, 13 (5.5%) belonged to a pair, and none were part of a group (Table 2). We recorded one less observation in the sociality portion of this survey in an effort to be conservative, as we were unable to precisely pinpoint one gecko's position. We used 237 exposure observations, of which 178 (75%) fell into the exposed category and 59 (25%) into the not exposed category (Table 3).

We recorded 237 temperature readings (Figure 1). The mean substrate temperature for adults was 24.9 °C (± 2.94), with a range of 16.4 – 31.5 °C (Table 4).

DISCUSSION—Our study generated five major results. First, adult *H. turcicus* were found significantly more often at higher perch heights than subadults. Second, both size classes appear to prefer a solitary existence, although subadults displayed a greater propensity for isolation than adults. Third, subadults tended to use exposed perches more than adults. Fourth, adults chose substrates of higher temperature and a larger substrate temperature range than subadults. Finally, adults were found at a higher mean substrate temperature with a smaller range during the spring survey (Survey 3) than during the fall survey (Survey 2).

Adult *H. turcicus* consistently used wall habitats > 1m above the ground surface regardless of the time of year. Although this result may be an artifact of the greater area available under the "high" category since most buildings were on average 3m in height, it seems unlikely as most adults were observed ≤ 1m from the roof awning. This high perch height could be beneficial for escaping predators, as we repeatedly witnessed startled geckos escaping into crevices in the roof awning. Our observations are unexpected when considering the results of Capula and Luiselli (1994), who showed that the diet of *H. turcicus* consisted mainly of ground-dwelling prey in its native Italy.

Subadults were typically observed on wall habitats ≤1m above the ground, particularly during our summer survey (Survey 1). This tendency by subadults to occupy low perch heights could stem from a variety of reasons. First, adults might relegate subadults to the lower portion of a wall, which might be sub optimal habitat with regards to predator vulnerability. This scenario might explain the significantly higher mortality rate found in geckos < 30 mm long in Florida and Texas (Selcer, 1986; Punzo, 2001).

A second explanation could be that the subadult age period is a dispersal stage of *H. turcicus*. Thus, subadults would be expected to frequent the lower portion of a wall, as they would be continuously on the move. This hypothesis was supported on several occasions by observations of subadults some distance away from any building or wall. Similarly, Rose and Barbour (1968) found juvenile (average 25.9 mm SVL) *H. turcicus* on sidewalks in Louisiana. Rose and Barbour (1968) also showed that hatchlings could survive without food or water for up to one month, and this resilient quality of subadults would be ideal for surviving the uncertainties of dispersal. Furthermore, subadult dispersal would be compatible with Selcer's (1986) findings in Texas, as dispersal would be expected to make subadults more vulnerable to predation and thus increase mortality rates.

A third explanation is that subadult preference for low wall perches might be a consequence of dietary differences. The preferred prey of subadults and/or prey size suitable for smaller mouths may be more abundant lower on walls. Saenz (1992) conducted a detailed dietary study on *H. turcicus* in Texas and found that small geckos tended to feed on small prey, and that diet overlap (Schoener's percent overlap index) decreased as the difference in gecko size increased. Saenz further concluded that a gecko's height on a wall greatly influenced its diet. These results suggest that geckos of different sizes have different diets, and that this difference might be a direct consequence of a gecko's height on a wall.

Sociality in the Mediterranean gecko during nocturnal foraging appears to be quite minimal. Both adults and subadults were most often solitary. This result supports the belief held by Klawinski (1991) that *H. turcicus* is territorial. Most of our pair and group observations involved only adults. Group sizes rarely exceeded three. We never observed aggressive displays or copulation. Although we were unable to determine the sex of individuals in pairs and groups, gecko pairings may have been associated with copulation or with communal nesting, which is common in this species (Selcer, 1986; Punzo, 2001). If reproduction is the basis for grouping, this may explain the almost complete lack of social grouping in subadults, a sexually immature life stage. The inclination for *H. turcicus* to be solitary does not imply that this species is unsociable. Other nocturnal geckos (*Nephrurus milii* and *Christinus marmoratus*) form large, non-random aggregations within retreat-sites (Kearney et al., 2001). Frankenberg (1982) showed that most vocalization in *H. turcicus* occurs from daytime retreats, and suggested that *H. turcicus* socializes during the daytime within retreat-sites, and forages in solitude during the night, rarely interacting with others.

Generally, *H. turcicus* remains exposed once it emerges from its retreat-site at night. Because the number of possible hiding places is difficult to quantify, frequent observations of exposed geckos may simply reflect our inability to detect all hidden geckos. This result also could be more a product of availability of hiding places than preference. Subadults had a greater propensity for remaining exposed than adults. This difference might stem from adult competition for hiding spaces, which could be intense if these spaces offer significant protection from predators. This subadult trend might also be an artifact of a lower incidence of hiding places situated at the bottom portion of walls.

The mean substrate temperature selected by adult *H. turcicus* was significantly greater than that chosen by subadults. Adults also were found over a wider range of substrate temperatures than subadults. These results could be a direct result of size, with larger individuals being able to both exclude smaller individuals from warmer surfaces and withstand more extreme temperatures due to a larger body mass that allows for a decrease in body heating and cooling rates (Bartholomew and Tucker, 1964). Adults were found at a higher mean substrate temperature, but displayed smaller range in these temperatures in the spring than in fall. Variability of substrate temperature might be lower in spring because of overall warmer ambient temperature, and thus explain our findings. Although these temperatures are lower than those previously measured (29.1°C, $n = 8$) by Angilletta and co-workers (1999), this is not entirely surprising as some species of nocturnal geckos thermoregulate and achieve their preferred body temperature during the day within their retreats rather than at night (Angilletta et al., 1999; Kearney and Predavec, 2000).

A final point when considering our results is the possibility of pseudo-replication in the data. For the fall survey, we visited the same 50 walls each week, whereas in the spring survey we visited the same 160 walls twice. These two sampling methods did not allow us to distinguish among individuals, and we likely counted the same individual more than once. Thus, our conclusions should be interpreted with some caution. However, despite these cautions, our results nevertheless provide insight for future investigators.

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Review

Lisa Jardine, *The Curious Life of Robert Hooke*: The Man Who Measured London, HarperCollins Publishers, Inc., New York, NY. 2004 ix + 422 pp, clothbound $27.95 (ISBN 0-06-053897-X)

Robert Hooke was one of the "Oxford Three" (Robert Boyle, John Mayow, and Robert Hooke) so named because they were associated with each other in the study of the gas laws and combustion. Robert Boyle is said to be the "Father of Chemistry", Mayhow left to become a physician, and Hooke is probably the most interesting of the three, though far less well known than Robert Boyle. That could change, thanks to this book (and Stephen Inwood's *The Man Who Knew Too Much*). Hooke has had a bad press because he and Sir Isaac Newton disagreed (not a hard thing to do given the character of Newton), and his efforts in the late 1660s may have been overshadowed by Sir Christopher Wren. But Hooke should be given credit, much more than he has received, for his work in chemistry, his description of sea shells, his understanding through study of fossils that the time frame of the Old Testament was not to be taken literally (a dangerous assertion to make at the time), and his creativity in designing early instruments (including a novel balance spring watch). He was the designer of Bethlehem (or Bedlam) Hospital, which was supposed to provide "palatial accommodation for London's disposed and insane". And he was appointed London's Chief Surveyor following the Great Fire of 1666, a position that speaks much for the contemporary respect for his ability and integrity. It is to his credit and the author's expository skills that the reader gains a better understanding of Hooke's character, including his integrity (which supported the Royal Society at a critical time in its transformation to a reputable scientific society). The author elucidates his achievements and the relationship to his birthplace (Isle of Wright) in an admirable, fascinating manner. By the 1670s, Hooke was well-placed financially and socially to have a happy comfortable remaining years. That this did not happen is clarified, "Only his tendency to be tempted into almost any scientific or technical argument, and his subsequent utter inability to back down or admit he might have been wrong . . ." Readers should enjoy this scholarly, but eminently readable, account of an interesting, but complex individual, who deserved to be better known.—Dean F. Martin, University of Sourth Florida, Tampa.

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