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Snake Hybridization: A Case for Intrabaraminic Diversity

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Abstract

Snakes have rarely been examined as examples of intrabaraminic variation due to the relative obscurity of knowledge regarding the subject of these secretive animals as well as the relative newness of the breeding of snakes. North American species of snakes of the genera *Lampropeltis, Pituophis*, and *Elaphe*, while classified in separate genera may actually be more closely related than evolutionary biology predicts.

This study examined intergeneric and interspecific hybridization of several species of colubrid snakes through the use of both natural breeding methods and scent disguise to fool the different species to interbreed. Eleven different species of three different genera were used in this experiment. Results of the crosses were as expected to resemble midpoints of color and pattern between the parental species. Banding patterns appeared to be dominant over blotches and stripes. The most interesting finding was that the amelanistic varieties of the California kingsnake, *L.g.californiae*, and the corn snake, *E.g.guttata* are apparently allelic forms of amelanism regardless of the fact that these snakes are members of different genera. When the two genera were crossed this albinism appeared in the F1 generation. All types of the hybrids produced were viable and fertile. As such, they are most likely examples of intrabaraminic diversity of created "kinds" rather than evolutionary speciation. This paper adds viability, homologous genes, and pigment variations to the list of character space criteria for recognizing baramins.

Keywords

Snake hybridization, Colubrids, Baramins, Evolution, Creation, Coloration, Striping, Banding, Melanism, Amelanism, Genetics

Introduction

The practice of hybridization has long been used by man to maximize our utilization of various plant and animal species. While most types of hybridization that take place today are with types of plants, there continue to be an increasing number of animal hybridizations occurring. Hybrid cattle, sheep, and swine are produced primarily for use in the food and textile industries. However, as our lifestyles have changed to generally provide us with more disposable income, other types of animal hybrids have been produced with the primary goal being to create new and unusual pets. Such is the case with the various wolf dog hybrids, exotic/domestic cat hybrids, and as this paper will examine snake hybrids.

The captive production of snakes is essentially in its infancy, only being performed with any degree of success or regularity since the mid-1970s. During this time, breeding of snakes was rarely accomplished because of the hit-and-miss methodology involved in artificially manipulating the laboratory environment in which to encourage the animals to breed; the knowledge had not yet been perfected. This previous fact, coupled with the relative scarcity of healthy breeding stock of any given species (breeders often having only one example of a species in their collections), hybridizations were performed, primarily to couple unpaired individuals. Many breeders were successful in producing a wide variety of crossbreeds. While these experiments were interesting, they were quickly abandoned by many because of the great degree of pressure placed on individuals to discontinue the practice as it was deemed contrary to the goals of captive breeding and conservation. Generally speaking, these crosses were between different subspecies and species of snakes as it was widely assumed that members of different genera would be too distantly related to produce viable offspring.

In the late 1980s, some individuals began experimenting with intergeneric hybridizations and were able to produce viable and fertile offspring between members of three genera of colubrid snakes: the kingsnakes, genus *Lampropeltis,* the rat snakes, genus *Elaphe,* and the pine snakes, genus *Pituophis.*

Problem

Hybridization experiments play an important role in establishing common ancestry. If organisms have the ability to hybridize, then they most likely have similar developmental routes. Baraminology (Wood, Wise, Sanders, & Doran, 2003) has been proposed as a method to examine the relationships between and among the original created biblical "kinds" and their descendents or baramins. This method upgraded the earlier baramin concepts by redefining some of the definitions and expanding the criteria for approximating the similarity in groupings. The expansion addressed the issues of biological character space, potentiality regions, and continuity/discontinuity descriptions. Holism was emphasized by looking at other similarity factors such as chromosomal, cellular, developmental, and anatomical levels of organization instead of using hybridization alone.

While the microevolutionary "speciation" of various types of snakes is not really seen as a problem by creationists; indeed, it is simply the expression of additional genetic material which was always present in snake baramins. This study will examine the viability of hybrids among three genera of colubrid snakes and suggest some biological characteristics that could add to the holistic similarity of various snake taxa.

Significance

This study will test the viability of interspecific and intergeneric snake hybrids. Making a close connection between members of different snake genera is important in circumscribing a created kind. Baraminology as a concept, as well as snake hybridization, have rarely been examined in detail for snakes and should increase the amount of available data significantly.

Literature Review

History

Snake breeding has only become commonplace during the last quarter of the twentieth century. Until that time, breedings were sporadic and were generally the result of a combination of an unknown set of criteria working together Eventually it was determined that among other factors, a period of brumation, or winter cooling was necessary (Bechtel, 1978; Markel, 1990; McEachern, 1991; Rossi, 1992). This cooling period served two purposes. First, it stimulated the production of sperm in males. Second, it stimulated ovulation in females. Currently, there are several hundred thousand snakes being routinely bred in captivity annually. There are very few snake species that are common in the pet trade that are not bred with regularity.

Definitions	
Albino	an animal or plant with a marked deficiency in pigmentation
Amelanistic	a reptile showing an absence of melanin, or dark pigment
Axanthic	a reptile showing an absence of xanthids, or the red-yellow pigments
Baraminology	the study of the biblically created "kinds"
Brumation	period of inactivity for cold-blooded animals, similar to hibernation in mammals, but not marked by the same degree of inactivity
Fl	first filial generation hybrid
F2	second filial generation hybrid
Holobaramin	a member of a created baramin that is surrounded by phyletic discontinuity, but not divided by it
Hybrid	the offpring of two animals or plants of different breeds, varieties, or species, especially as produced through human manipulation for specific genetic characteristics
Hypomelanistic	a reptile showing a less than normal amount of melanin. This is a highly variable state, ranging from complete absence of melanin to a very minimal absence.
Hypoxanthic	a reptile showing a less than normal amount of xanthids. This condition can be relatively difficult to identify.
Iridocyte	pigment producing cell responsible for the production of irids that create the reflectiveness and intensity of all colors. The iridocyte produces its definition in the amount of stacked cells present in each zone of the dermal layer.
"Jungle Corn"	term coined to refer to a hybrid with the parental species of both the California kingsnake, *Lampropeltis getula calfornae*, and the corn snake, *Elaphe guttata guttata*. This term is used for the similarity in coloration to another snake variety, the "Jungle" carpet python, *Morelia variagata cheyni*.
Leucistic	a reptile missing all skin pigments except for iridophores. These animals are marked by an all white skin with no pattern and blue or black eyes.
Melanistic	an animal with an abnormally high concentration of melanin
Melanocyte	pigment producing cell responsible for the production of melanin, or black and brown pigmentation
Piebald	a reptile missing all pigment over several areas of the skin. This mutation is not always consistent and can be marked by the missing of pigment in various places. Similar to the vitiligo ailment in mammals.
Xanthic also known as hyperxanthic	a reptile showing an abnormally high concentration of red or yellow coloration
Xanthocyte	pigment producing cell responsible for the production of xanthids, or yellow and red pigmentation

Hybridizations

The practice of snake hybridization is often thought by most snake breeders to be the antithesis of the goal of captive propagation. This is because a large number of these breeders have a particular desire to be seen as conservationists who are keeping endangered gene pools "alive." The irony here cannot be ignored because the breeding of snakes had capitalism as its original impetus. Furthermore, it is highly unlikely that zoos would ever turn to private breeders for stock with which to repopulate an area from which snakes were extirpated. At any rate, because hybridization does not "conserve" the supposed endemic variation of species, it is viewed as anathema. Because of this, scant little research has been done on the subject; even less has been published. For the most part, unusual hybridizations are claimed to be either accidental or to have been captured from the wild for study. Bailey (1942) and Murphy and Crabtree (1988) have published accounts of apparent interspecific hybrid rattlesnakes that were encountered in the wild.

Perhaps the first intentionally produced hybrid of this sort was described by Klauber (1956). He succeeded in producing a hybrid between a southern Pacific rattlesnake, *Crotalus viridis helleri,* and a red diamond rattlesnake, *C.ruber ruber.* Only recently have reports of intentional intergeneric and interspecific hybrids being produced become more commonplace. Hennigan (2005), Markel (1990), McEachern (1991), Fankhauser (1996) and Staszko and Walls (1994) have all reported intergeneric hybrids between California kingsnakes, *Lampropeltis getula californiae,* and corn snakes, *Elaphe guttata guttata.* Additionally, these same sources have made mention of various other hybridizations, both intergeneric and interspecific, among members of *Lampropeltis, Elaphe, Pituophis*, and *Bitis* (the rhinoceros vipers; Rundquist, 1993).

While the generally self-imposed moratorium on intentionally producing intergeneric and interspecific types of hybrids has been in existence for some time, due to the conservatory reasons previously mentioned, no such obstacles have been in place for subspecific intergradation as it is well known that intergrades regularly occur in the wild. Ross (1978) was one of the few who began to speak out against the practice of sub-specific hybridizations. The primary reason that intraspecific hybridization is generally accepted is because these intergrades naturally occur where two different subspecies' ranges meet. They are assumed to be "natural" and as a result are not a threat to the genetic integrity of wild or captive stock. Various types of wild intergrades are well documented (Barker & Barker, 1994; Conant & Collins, 1991; Markel, 1990; Mehrtens, 1987; Rossi, 1992, 1995; Shaw & Campbell, 1974; Stebbins, 1985; Williams, 1988). In laboratory settings such intraspecific hybrids have also been examined rudimentarily by Bechtel and Bechtel (1985) and in lizards by Hall and Selander (1973).

Recently, extensive experiments have been conducted regarding interspecific hybridizations in the lizard genus *Lacerta* by Arrayago, Bea and Hevlin (1996), Arevalo, Casas, Davis, Lara, and Sites (1993), and Cooper (1965). While these experiments are not with snake species, their findings have implications for snakes as well.

Genetic pigments

In mammals, skin pigmentation is composed of three types of color, melanin (black/brown), eumelanin (red/yellow), and white. Similarly, reptilian coloration is controlled by three pigment producing cells; melanocytes, xanthocytes, and iridocytes, although there is a little difference in function of the cells. Melanocytes control the black/brown colorations. Xanthocytes control the red/yellow colorations. Iridocytes control the reflectiveness and intensity of the colors of the skin. These cells do not synthesize pigments, but help in color production because of their physical properties. They contain deposits of aminto acids in reflecting platelets arranged in oriented stacks. Reflection and refraction of light result in hues of green, blue, red, and brown. The shape, size and orientation of the platelets determine the resulting reflected colors (Bechtel, 1995).

Mutations have been identified in reptiles that control expression of each of these three pigment cells. Melanistic, or hypermelanistic, snakes possess an increased amount of melanin, resulting in an overall brown-black color. Amelanistic snakes are missing all melanin and thus possess only coloration controlled by the other two pigments. Hypomelanistic animals show a great degree of variation as they can be classified as such by possessing any of the range of melanin from a normally pigmented individual to an amelanistic individual. You might wonder why we have not specifically referred to albinos, although one would think that this would be a common term when talking about color abnormalities. Albinos exist in reptiles, yet because the term is not as descriptive as we would like, many reptile scientists and hobbyists prefer not to use the term. In other words, an albino could be categorized as an animal missing only a little melanin or one missing all melanin. Rather, we prefer to use the more descriptive terms of amelanistic, axanthic, etc.

Xanthic animals possess an abundance of red or yellow coloration. Axanthic snakes are missing these colors and are typically black, white, and/or blue. Similarly, it is difficult to identify snakes that possess a mutation of the iridophores, although it is believed that all-white, or leucistic, and partially white, or

piebald, snakes display mutations of this pigment. This is assumed because these snakes are missing all pigmentation in the skin; and if the irridophore is to make an impact on the final coloration of the animal, then it would presumably be absent in an entirely unpigmented animal.

Additionally, snakes that possess more than one type of pigment abnormality have also been selectively produced. Such individuals phenotypically display axanthism and amelanism (termed "snows"), axanthism and hypomelanism (termed "ghosts"), melanism and amelanism, and leucism and amelanism (Bechtel & Bechtel, 1985, 1989; Fankhauser, 1996). Refer to Figure 1 for a photograph of a snow corn snake.

Currently, all mutations involving pigment have been shown to be inherited as recessive traits and all are inherited in a simple Mendelian manner. However, in two forms of hypomelanism, hypomelanism in the Durango kingsnake, *L. mexicana "greeri"* (Triem, personal communication), and the Cape gopher snake, *P. catenfer vertebralis* (Weisman, personal communication), there appear to be several controlling genes which result in a number of unique phenotypes, which can culminate in the production of an amelanistic snake.

Pattern

A few types of pattern anomalies have been identified in snakes. Generally these abnormalities change the typical pattern to a patternless or longitudinally striped pattern. Striped pattern mutations have been identified and propagated in the following species: *P. c. catenfer, L. g. californiae, E. g. guttata, B. constrictor constrictor, P. regius, P. reticulatus, L. calligastar calligastar, L. alterna, R. leconte E,* and *Morelia spilota variegata.* All are controlled by recessive genes except *L. g. californiae,* where the two pattern genes are codominant; *P. c. catenfer,* where the striping pattern is dominant; and *P. reticulatus,* which has just recently been shown to be the only snake mutation where the dominant trait possess a unique phenotype in its homozygous form (Barker & Barker, 1997). This reticulated python, which first appeared as a dominant heterozygous mutation was coined the "tiger retic" and showed the normal pattern obscured into a type of zig-zag blotch the entire length of the snake. However, when two tigers were bred together it was discovered that in the homozygous form, the dominant "tiger" mutation resulted in a fully striped animal which was then called the "super tiger" albeit incorrectly. No other dominant striping mutation displayed itself differently in both its homozygous and heterozygous states. Interestingly, *Ms. variegata* is the only species that has shown both recessive and dominant striping mutations.

Figure 1. Corn snake *E.g. guttata*, which is homozygous recessive for both amelanism and axanthism. This type of mutation is called a snow corn because of the overall white coloration.

Other than striping mutations, there is a completely patternless mutation of the Southern pine snake, *P. melanoleucus mugitis,* which displays no striping or semblance of a pattern. Additionally, a mutation exists in the corn snake that appears to shunt the normal pattern enough to offset the blotches resulting in a zig-zag pattern, also inherited recessively.

Apparently unique to a single species of North American rat snake, *Bogertophis subocularis,* the wild-type pattern possesses both a striped pattern and a blotched pattern that are displayed concurrently but inherited independently. This is known because two pattern mutations have been identified which show each pattern separately. In the west Texas population of these animals, there exists a naturally occurring population centered around one town that is made up largely of individuals missing the stripes. This mutant is called the "blond" phase and shows only doughnut shaped blotches (Tennant, 1985). Additionally, animals have been produced in captivity which are missing the blotches but still possess the stripes. As of this writing, the two mutations have not been combined, but would presumably result in a patternless, tan snake.

Baraminology

Marsh (1976) stressed the importance of hybridization data to establish common ancestry. If animals have the ability to hybridize, then there is a direct link to the biblical pattern of organisms to reproduce after their created "kind." ReMine (1990, 1993) proposed a new method of biosystematics which he called "Discontinuity systematics." Group membership in his four groups was based on continuity through common descent. The boundaries of the groups were defined by either continuity

Species studied	
L. m. mexicana	San Luis Potosi King
L. m. "greeri"	Durango Mountain King (Figure 2)
L. m. "thayeni"	Nuevo Leon King
L. pyromelanapyromelana	Arizona Mountain King
L. z. agalma	San Pedro Mountain King (Figure 3)
L. alterna	Gray-banded King (Figure 4)
L. nuthveni	Queretaro King
L. g. californiae	California King (Figure *5)*
P. m. melanoleucus	Northern Pine
P. c. catenfer	Pacific Gopher (Figure 6) *E. g. guttata*—Corn (Figure 7)
E. obsoleta obsoleta	Black Rat (Figure 8)
L. triangulum sinaloae	Sinaloan Milk (Figure 9)
Additionally, amelanistic and axanthic lineages *of* *L. g. californiae* (Figure 10), *P. c. catenfer* (Figure 6), and *E. g. guttata* (Figure 11), as well as striped varieties *of* *L. g. californiae* and axanthic strains of *E. g. guttata* were utilized.	

Figure 2. Durango mountain kingsnake, *l.m. "greeri."*.

Figure 3. San Pedro Mountain kingsnake, *l.z.agalma*.

Figure 4. Three variations on the wild-type gray-banded kingsnake, *L.alterna*. In this highly variable species, while the background colors can vary in intensity, there exist two distinct forms of pattern: the Blair's phase, consisting of red-orange saddles on a gray background and the alterna phase, consisting of thin ted bands alternating with thin black bands. While examples of both phases were used in hybridizations, it appears that only the Blair's phase surfaced in the F1 and F2 generations.

Figure 5. Wild-type California kingsnake, *L.g.californiae*. This is an aberrant form which combines the two known wild-type patterns of banding and striping.

Figure 6. Wild-type and amelanistic forms of the Pacific Gopher snake, *P.c. catenfer*.

Figure 7. Wild-type corn snake, *E.g. guttata.*

Figure 8. Wild-type black rat snake, *E.o.obsoleta.*

Figure 9. Sinaloan milk snake, *L.t.sinaloae.*

or discontinuity using four criteria. Wise (1990) formulated another biosystematic method which he called "Baraminology." He first redefined Marsh's baramin to include the first individual of the created kind (archaebaramin) and all its descendents. Then, he identified various criteria by which membership might be defined. In his "Practical baraminology" paper (Wise, 1992) he integrated ReMine's criteria

Figure 10. Amelanistic banded California kingsnake *L.g. californiae.*

Figure 11. Amelanistic corn snake, *E.g.guttata.*

and his into a list of twenty questions that could be asked about organismic relationships. Scherer (1994) defined hybridization in terms of basic types "Two individuals belong to the same basic type if (i) they are able to hybridize …(ii) they have hybridized with some third organism."

While there is generally no problem to the creationist regarding the created "snake" baramin (the biblically created kind of animal), there may be some disagreement as to how many holobaramins (a classification relating to types of animals which can interbreed with each other, but not with different holobaramins) may make up the snake baramin. While evolutionists continue to classify snakes into more and different species, it may become apparent that due to the hybridization ability of certain species, they may in fact be members of the same holobaramin rather than different "species" or even holobaramins. Thus, it can be said that the "speciation" of many members of the North American colubridae is in actuality a blossoming of the natural genetic material already present in the created holobaramin (Javor, 1991; Kautz, 1991; and Wise, 1992). Regardless of what may be learned by the current process of DNA strand hybridizations, there is little doubt that laboratory manipulation of hybrids can be significant in and of itself.

Materials and Methods

Breeding stock

Several species of snakes were used in this research. For the purposes of this study, all breeding stocks were at least one generation removed from wild stock. Because no genetic mapping was done of the parental animal's DNA, we cannot say with complete accuracy that every snake used in this study was in fact the species that they were purported to be. However, the sources of our stocks, being primarily descendants of animals which we collected or which were collected by close friends lead me to confirm the validity of the designations. Other breeding stocks which were used were obtained from breeders with excellent reputations who would not have provided us with animals of dubious ancestry.

General care

All breeding stocks were maintained in a separate, climate-controlled room. Temperature was kept at a constant 26.7°C and a light cycle of 16 hours of daylight per day.

Cages were commercially available Rubbermaid™ storage boxes measuring 56.8cm×41.7cm×15cm for adults and smaller 34.5cm×21cm×9cm storage boxes for hatchling sized animals. Occasionally, commercially available polystyrene storage containers were also used. These measured 41cm×28cm×10.6cm for adults and 32cm×17cm×9.6cm for juveniles. A separate heating element (heat tape—commonly used to prevent freezing of water pipes) was incorporated into the wooden caging racks, resulting in a temperature of 32.2–33.5°C running underneath the cage about two-thirds the distance from the front of the cage. Cage litter was composed of chipped aspen and pine shavings. Water was offered for two days at a time, once every two weeks.

Depending upon personal preference, animals were fed various sizes of laboratory mice and rats which were frozen/thawed, live, or recently killed. Food was offered a minimum of twice a week with as much regularity as possible. However, individuals did not always feed depending upon health, whether the animals were preparing for ecdysis, etc.

Breeding

To stimulate ovulation, sperm production, and general breeding behavior, it was necessary to put snakes through a cooling period. For ease of cooling, this brumation was generally allowed during the winter months. For the purposes of this study, brumation was allowed during the months of December, January, and half of February.

During this time, air temperature in the facility was cooled to a constant 13°C. Because enzymes helpful in digestion are slowed during this period, food was not offered at this time. However, water was offered with the same regularity. Snakes were brumated in the same cages in which they were normally kept and the light cycle was changed to a period of 24-hour darkness.

Subsequent to brumation, snakes were warmed up gradually in mid-February and returned to the regular 16-hour daylight, 26.7°C air temperature with supplemental heating tape. Normal feeding patterns were generally resumed within two to three days. At this time, males showed breeding behavior immediately; however, females were not yet receptive. Sexes were kept separate until breeding. Between one and two months after being removed from brumation, female snakes began to ovulate and it was at this time that they became receptive to a mate. Ovulation was verified through manual palpation of the female. The snake was held suspended in the air with one hand. The other hand, covered with material to facilitate smooth movement over the snake, was encircled around the snake with the thumb being dramatically upthrust into the body of the snake about $\frac{1}{3}$ posterior to the head and slowly moved posteriorly. If ovulation had occurred, the ova were felt as several hard, marble-sized lumps one-half to two-thirds down the length of the body. Once ovulation had been confirmed, breeding was attempted at once.

Generally speaking, all hybridizations occurred without manipulation as a normal breeding process. However, occasionally some males would display no interest when placed with a female. As a result, three other methods were attempted to entice the males into breeding.

These methods are outlined here:

Figure 12. Hybridization between an amelanistic Queretaro kingsnake, *L. ruthveni* and a gray-banded kingsnake, *L. alterna*. In this figure the method of accomplishing these types of breedings is clearly illustrated. The anterior portion of the male is mounted on the torso of a female amelanistic Queretaro kingsnake, while his tail is breeding with a female gray-banded kingsnake.

(1) The male snake was placed with an ovulating female of his own species. Subsequent to the female being mounted, but prior to insertion, the tail of the breeding male was removed from said female and placed on top of a female of a different species, after which breeding proceeded, with the front of the male's body on one female and the rear on another (Figure 12).

(2) Newly shed skins from females of the same species as the male were placed into the cage of an ovulating female of a different species to transfer the appropriate scent into that female's cage.

(3) A male was placed into a cage containing a female of his species and a female of another species. Once breeding activity began, the female of the same species was removed.

After a breeding was confirmed visually, a sperm sample was removed from the cloaca of the female by manually pushing the fluid out and examined under a microscope. Once a viable sperm sample was taken from a female, this female was bred only with the male that originally provided the sample to ensure there was no extraneous cross-fertilization. There was one exception to this methodology to be mentioned later.

Approximately one and one-half months after the first breeding has taken place, the female entered a pre-egg-laying shed, roughly ten days after which she laid a clutch of eggs. The eggs then hatched between 60–70 days after laying when incubated at a temperature of 26.7–29°C. Depending upon the overall health of the female, after laying her eggs, she was power-fed and artificially forced into ovulating again, thus producing another clutch of eggs during the same season.

The eggs were incubated in small Rubbermaid™ storage boxes on a mixed medium of 50% vermiculite and 50% perlite. The medium was kept moist and the eggs were observed and misted directly with distilled water twice a week.

Data collection

Breedings between various species were performed over a period between 1992 and 1999. In most cases, the breedings were only carried to the F2 offspring. The phenotypes of the parents and offspring were noted and recorded. Over this time period, over 200 offspring were produced for examination in this experiment.

While data from this type of experiment are not conducive to statistical calculations, data regarding production of various mutant phenotypes was examined to determine adherence to Mendelian probabilities.

Table 1, Results of first generation breedings. Number of eggs laid, number hatched, and viability (hatching percentage) according to species and year of breeding were recorded. Males are listed first in each cross.

Parental Species	Year	# Laid	#Hatched	Viability
L. alterna × *L. z. agalma*	1995	6	1	17%
	1998	12	12	100%
L. p. woodeni × *L. alterna*	1994	6	4	67%
	1996	14	10	71%
L. alterna × *L. m. mexicana*	1996	5	4	80%
	1997	4	3	75%
L. ruthveni × *L. alterna*	1997	15	10	67%
	1998	28	22	79%
L. p. woodeni × *L. m. greeri*	1996	4	1	25%
L. ruthveni × *L. m. greeri*	1996	6	6	100%
L. p. woodeni × *L. m. thayeri*	1996	5	3	60%
L. p. woodeni × *L. m. mexicana*	1995	5	4	80%
L. ruthveni × *L. m. thayeri*	1997	5	3	60%
L. g. californae × *L. t. sinaloae*	1995	6	4	67%
E. g. guttata × *L. g. californiae*	1993	5	3	60%
	1994	18	8	44%
	1995	11	5	45%
E. g. guttata × *P. c. catenifer*	1993	8	2	25%
E. g. guttata × *E. o. obsolete*	1997	14	14	100%
	1998	10	10	100%
E. o. obsoleta × *P. m. mugitus*	1996	8	6	75%
P. c. sayi × *P. m. mugitus*	1994	4	3	75%
			Average Viability	67%

Pictures

Photographs were taken of some of the parental stock as well as F1 offspring. For these pictures, a Nikon™ F1 SLR camera was used with 400 ASA Kodak™ color print film. Additionally, photographs were taken of any anomalies as far as color and pattern as well as of any F2 offspring which were unusual enough that they were markedly different from parental types—so much so as to discount "normal" variation.

Figure 13. Intergeneric F1 hybrid between a black rat snake, *E.o. obsoleta*, and a northern pine snake, *P.m. melanolecus*.

Figure 14. Two F1 interspecific gray-banded kingsnake hybrids. The photograph on the left is a hybrid between the gray-banded kingsnake, *L.z.agalma* and the Arizona mountain kingsnake, *L.p.woodeni*. The photograph on the right is a hybrid between the gray-banded kingsnake and the San Pedro mountain kingsnake, *L.z.agalma*. These two types of mountain kingsnakes occupy similar ecological niches as well as being similar in color and pattern. This similarity carries through to the hybrids. While each of these hybrids shares one parent, the other parent of each is a different species, yet the F1 hybrids are nearly identical.

Figure 15. Interspecific F1 hybrid between the Arizona mountain kingsnake, *L.p. woodeni* and the San Luis Potosi kingsnake, *L.m. mexicana*.

Figure 16. Interspecific F1 hybrid between the gray-banded kingsnake, *L. alterna*, and the San Luis Potosi kingsnake, *L.m. mexicana*.

Figure 17. Interspecific F1 hybrid between the Durango mountain kingsnake, *L.m. "greeri"* and the Queretaro kingsnake *L. ruthveni*.

Figure 18. Interspecific F1 hybrid between the Sinaloan milk snake, *L.t. sinaloae*, and the California kingsnake, *L.g. californiae*.

Figure 19. Wild-type F1 hybrid jungle corn, *E.g. guttata* × *L.g. californiae*.

Records

Detailed records were kept consisting of feedings, breeding dates and frequency, dates of egg laying, hatching, and number and variety of offspring.

Results

For the most part, breeding success was achieved

Figure 20. Amelanistic F1 hybrid between a Pacific gopher snake, *P. catenifer*, and a corn snake, *E.g. guttata*.

Figure 21. Intergeneric F2 hybrid, the result of a backcross of an F1 hybrid jungle corn, *E.g. guttata* with a California kingsnake, *L.g. californiae*. This F2 is 75% California kingsnake and 25% corn snake, yet is indistinguishable from a pure California kingsnake. This individual came from a clutch with a relatively high fertility rate of 88%.

Figure 22. Amelanistic F1 hybrid jungle corn, *E.g. guttata* × *L.g. californiae*.

through a rigorous period of trial and error, while the methodology was being hammered out. The various types of hybridizations that were able to be performed are summarized in Table 1, which shows that the average fertility rate in these initial F1 crosses was 69%. Photographs of these offspring can be seen in Figures 13 to 20. The only breedings that were recorded were those that had been confirmed through a cloacal sample of sperm taken from the female within a few minutes of breeding. This was done because there were naturally some breeding seasons where the male or males had not been brumated to the degree necessary for sperm production to begin. There is an outside possibility that sperm storage from the previous season could have effected fertility or production rates, however this is unlikely due to the fact that most females were virgins in their first season, and those animals which were used in the F1 generation crosses were bred to members of their own species the previous year and the appearance of the offspring would have confirmed either hybridization or sperm storage breedings.

Some of these breedings were between very similar species, both in habitat and color/pattern. The most notable exceptions being the breedings between the corn snake, *E.g.guttata,* and the California kingsnake, *L.g.californiae* (see Figure 19), and the breedings between the corn snake and the Pacific gopher snake, *P.c.catenfer* (see Figure 20). These intergeneric crosses cannot really be said to resemble either of the parental species, instead appearing to be entirely different animals. On the other hand, it can be seen that for the most part, the interspecific crosses showed more of a similarity to their respective parents.

Although most of the breedings were among normally colored members of the species, the California kingsnakes and corn snakes provided the infusion of amelanistic genes, resulting in the production of albinos, as seen in Figures 20 to 22. In the case of the corn snake, the gene for axanthism also resulted in the production of the more unusual "snow" variety of hybrid as will be discussed later.

After these initial F1 hybrids were raised up to breeding age, further manipulations were performed. In Table 2 we can see the results of the two types of backcrosses that were performed. These backcrosses were only done with the intergeneric cross of the "jungle corn" and not with the "gopher corn" hybrids of *E.g.guttata* and *P.c.catenfer.* The backcrosses were made with the F1 hybrid offspring back to the parental species of the California kingsnake and separately to the corn snake. These crosses resulted

Table 2. Results of second generation backcrosses. These crosses were made with the male F1 offspring of the breeding of a California kingsnake, *L.g. californiae*, to a corn snake, *E.g.guttata*, and each female of the respective parental species. In each of these breedings, the male is listed first.

Parental Species	Year	#Laid	# Hatched	Viability
L.g.californiae × *E.g.guttata* × *L.g.californiae*	1996	8	7	88%
L.g.californiae × *E.g.guttata* × *E.g.guttata*	1996	12	10	83%
			Average Viability	85.5%

Table 3. Results of second generation breedings among F1 siblings. Number of eggs laid, number hatched, and viability (hatching percentage) of first generation crosses according to species and year of breeding were recorded.

Parental Species	Year	# Laid	#Hatched	Viability
L. p.woodeni × *L alterna*	1998	10	6	60%
L. p. wooden × *L. m. mexicana*	1997	5	0	0%
	1998	6	4	67%
L. ruthveni × *L. m. greeri*	1999	7	3	43%
L. g. californiae × *E. g. guttata*	1995	12	0	0%
	1997	20	12	60%
	1998	12	0	0%
E. g. guttata × *E. o. obsoleta*	1999	8	6	75%
			Average Viability	38%

in fertility rates of 88% and 83%, respectively, with a combined fertility of 85%.

The average fertility of these backcrosses was much higher than the results that were achieved when the F1 hybrids were bred to one another, regardless of whether or not they were siblings. As can be seen in Table 3, the average fertility of F1 hybrid breedings was merely 39%.

The last type of hybridizations that were performed was between hybrids of differing parental strains. In other words, a hybrid of two species was bred to another hybrid of two different species. This type of breeding resulted in offspring which each possessed 25% of the genetic material of four different species. The results of these breedings can be seen in Table 4 where the total fertility rate of these types of breedings was 70%.

Discussion

Sterility

According to Haldane's rule (Bessey, 1908), which states that in the F1 generation of a hybrid, whether interspecific, intergeneric, etc., the heterogametic sex, that is, the sex which has two different chromosomes (male), is often sterile. Thus, intergeneric, and even interspecific, snake hybrids should have infertile males. However, in all the cases which were examined in this study, the male hybrids were fertile and produced offspring, although they showed higher fertility when bred to other species and other hybrids than when bred to their F1 counterparts. In fact, these hybrid males had higher sperm counts (data not presented here) and sperm activity than in many other snake species that the researcher has regularly bred. However, this high rate of male fertility did not result in greater hatching percentages (viability) as would be predicted between F1 hybrids. The implications of these results will be discussed later.

Table 4. Results of breedings between F1 hybrids of differing parental strains. Each of these F2 offpsring was a combination of four different species. Number of eggs laid, humber hatched, and hatching percentage were recorded. Males are listed first in the cross.

Parental Species	Year	#Laid	# Hatched	Viability
L. ruthveni × *L. m. "greeri"* × *L. alterna* × *L. p. woodeni*	1999	6	4	67%
L. z. agalma × *L. alterna* × *L. m. mexicana* × *L. p. woodeni*	1999	4	3	75%
		Average Viability		71%

How can we rectify this apparent inconsistency? It is entirely possible that this high rate of viability allows the organism the greatest latitude possible to make the best use of as many productive genes as possible. In fact, the direction may be toward that of further hybrid allele diversity. This might account for the higher fertility of clutches seen in F1 backcrosses, which had an average fertility of 85%, as opposed to F1×F1 crosses, with a relatively low fertility rate of 39% (see Tables 2 and 3). From a creationist's point of view, the animal is showing an increase in alleles on already present genes, but the greatest benefit is realized from an occasional infusion of unique alleles and returning these alleles to other varieties rather than a continual radiation farther from the parental species. In this way, hybrids are more successful, but not to the point of extreme speciation. While it might seem that the intergeneric aspects of some of the breedings have been overemphasized, it is significant in terms of supporting the baramin concept.

All of the snake varieties examined in this study are members of the same family, the Colubridae (comprising king snakes, rat snakes, gopher snakes), which are all members of the same holobaramin and thus related closely enough so that hybridization is not unexpected, at least to the creationist.

Looking at the hatching percentage of the F1 crosses and F2 crosses, what is primarily notable is the vast difference between the viability rates of each type of cross. This rate of viability was not determined by sperm count because whenever sperm samples were taken, sperm were always very motile and numerous, particularly in the hybrids, but was instead determined by hatching percentages when compared with number of eggs laid. A much higher hatching rate was seen in the initial crosses of different species and genera, as can be seen in Table 1 with a rate of 69%, than was seen when the F1 offspring were bred together with the 39% fertility rate (Table 3). This should not necessarily be seen as unfitness of the hybrids, because when they were back-crossed to either of their parental species, they showed the similarly high fertility rate that was shown in the initial cross (Table 2). Of particular note

is that while the offspring of the backcrosses possessed 75% of the genetic makeup of one or the other of their parental species, the vast majority of these young were indistinguishable from the species of which they possessed this three-quarter gene makeup. Similarly, when hybrids of different parental species were bred together, resulting in a quad-cross (Table 4), there was also a relatively high percentage of hatching at 70%. Evidently, there is some mechanism present which discourages the breeding of F1 individuals of similar genetic backgrounds. It is entirely possible that there is a compatibility barrier between the lock-and-key type of interaction of the sperm head and the membrane of the egg. F1 hybrid eggs must naturally be more receptive to parental gametes than to the gametes of F1 siblings.

Another study has produced similar results. Dosselman, Schaalje, and Sites (1998) examined hybrid zones *of Sceloporus*. As many as five genotypes were identified, such as F1 hybrid, F1 backcrosses, etc. It was found that each of the different types of hybrids showed more genetic stability than any of the parental species. It would thus appear that it is of "evolutionary" benefit for the animals to hybridize instead of remaining within their defined species. In other words, breeding to expand the gene pool as would occur during hybridization is more successful over breeding which would restrict the gene pool as would occur in-line breeding or inbreeding with genetically similar individuals.

Initially, this can be viewed as contrary to the evolutionary idea of speciation with regard to hybridization—something that the evolutionist would embrace as it tends to negate the practice of hybridization in the wild, thus leading to speciation and instead lean towards variation within species as being the basis for speciation. In other words, this fact might tend to support the evolutionary divergence from each successive branch of the tree rather than the joining of two branches to return to the original form of the species. However, upon further examination, it might instead be seen as God's design to promote the continual injection of heterogeneous genetic material by increasing the fertility rate between relatively dissimilar animals. This would seem to strengthen the entire holobaramin instead of it being weakened by the continual inbreeding that is necessary for evolutionary speciation to occur. Thus, the variation within the created baramin is further amplified by the fact that snakes are better off breeding with other snakes that possess as many traits which are different from their own as possible. This is an interesting and telling fact which was unexpected yet very remarkable. We are thus given a perfect example of God's providence inherently displaying itself in His creations.

Loci of Amelanism. An important result of these experiments, which also served to show the closeness of the relationship between corn snakes and king snakes, was establishing that the loci of amelanism in both *Elaphe* and *Lampropeltis* are exactly the same. Several factors can contribute to abnormal melanization:

1.	defective cell differentiation in the embryonic neural crest
2.	defective migration of chromatophores from the neural crest
3.	defective synthesis of protein within melanophores
4.	absence of tyrosinase inhibitors.
5.	dietary deficiency
6.	presence of inhibitors in the tyrosine to melanin pathways
7.	lack of useable tyrosine
8.	inability to synthesize tyrosine
9.	abnormal phenylalanine metabolism

Baramins/hybrids

It *is* perhaps necessary to keep in mind that just because there may be a lack of hybridization data, giving the impression that particular hybrids are rarely seen or worked with does not mean that these hybrids cannot occur. However, on the other side of the coin, successful hybridization is considered very definitive evidence that two animals have a close genetic relationship. While hybridizations between members of the same baramin are common and allowable to the creationist, between baramin hybrids are not possible by definition. Therefore, if two animals can interbreed, we know that they are from the same baramin. For the most part, creationists do make use of this type of data by then classifying Linnaean species into related monobaramins.

While the creationist can embrace baraminology as a classification system by stating that organisms are descended from their kinds and thus are related, we should not be afraid of the notion of speciation in terms of maximizing diversity. After the Flood, organisms were subjected to a variety of stresses. The way these problems were dealt with was through speciation. However, we should not completely give the animals credit for adapting and overcoming their hardships. It is not a question of whether God designed them for a function, or whether they adapted on their own, but rather a combination of the two. God provided the animals with the ability to adapt should the need arise, thus allowing the best combination of design and adaptive capability.

The arguments can be further honed by discussing varieties, or subspecies within the organization of a species. While this additional splitting of organisms is relatively closely tied to evolutionary phylogeny, it also works well with intrabaraminic phylogeny. The creationist can easily rectify different varieties with his beliefs.

Despite the variation of expression, both of these apparently "unrelated" snakes happen to display the same type of melanin mutation. Of course, this can

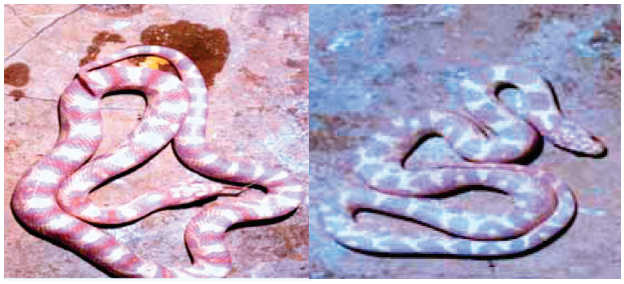

Figure 23. Amelanistic F2 hybrid jungle corns, *E.g. guttata* × *L.g. californiae*. Both animals are clutch mates, yet have substantially different patterns and coloration. The snake in the left photo clearly demonstrates some of the aberrancy passed on to it by its grandmother.

be attributed to the fact that it is the most common melanin mutation among all snakes, but it is more likely simply due to the fact that these snakes are members of the same holobaramin and possess the same potential for mutation in their genes.

The first of these hybridization experiments was carried out using a male "snow" corn snake, *E.g.guttata,* which was homozygous recessive for both axanthism and amelanism and a female amelanistic California kingsnake, *L.g.californiae.* Because it had been previously determined through several breeding experiments that there were several species of snakes which showed non-allelic forms of amelanism, and at least one species which showed non-allelic forms of axanthism, it was assumed that members of two different genera would not possess allelic forms of amelanism. Therefore, the assumption was that in a first generation hybridization between two animals that were both homozygous recessive for amelanism, the F1 offspring would be of the wild type. However, when this first clutch of hybrids hatched, all three of the young were amelanistic (Figure 22).

These results indicated that there was some type of gene homology between the two species and suggests that they possess a much closer relationship than was initially assumed. Indeed, if nothing else, it shows that some genes controlling pigmentation for snakes may reside at the same locus in at least these two genera, and quite possibly members of other genera as well.

Striping

As mentioned earlier, striping in the California kingsnake is co-dominant to the banding pattern and striping in the corn snake is recessive to the normal blotched pattern. The striping of the animals would not necessarily be significant, but the original female amelanistic California kingsnake that was used in the study was of an aberrant pattern and thus carried both the striping and banding patterns. This trait did not display itself in the F1 generation as would be expected if the pattern was co-dominant to the blotched pattern of the corn snake as it is to the banding pattern in the king. Instead, aberrant individuals began appearing in the F2 generations of the hybrids indicating that while the striping was co-dominant in *Lampropeltis,* striping is apparently always recessive in the corn snake, regardless of whether this mutation comes from the other genera or *Elaphe.* An example of this aberrancy is shown in Figure 23.

Axanthism

Yet another finding of this study that further seems to support the close relationship of these two genera of snakes is in the inheritance of the axanthic color mutation. While it was established that the amelanistic mutations occur on the same loci in each of the two genera, it was also shown that the axanthic trait of the corn snake is inherited in a simple Mendelian manner in both species as well.

Because the original male corn snake that was used in this experiment was a "snow," meaning that it was homozygous recessive for not only amelanism but also axanthism, it was able to pass these alleles on to its offspring. As a result, all of the F1 young that were produced from these breedings were heterozygous for the axanthic trait. Therefore, in the F2 generation some of the offspring that were produced displayed the similar "snow" coloration (Figure 24). While this demonstrates that the axanthic mutation is inherited the same in both genera, the findings are not as monumental as those for amelanism because no axanthic California kingsnake was available to perform the hybridizations. So it cannot be determined whether or not the axanthic mutations in the two species are also located on the same location of the chromosome.

Figure 24. Intergeneric F2 jungle corn hybrid. This is the first snow jungle corn ever produced and displays the two recessive colorations of amelanism and axanthism simultaneously.

Phenotype of pattern and coloration

The only major type of pattern mutation that was studied in this experiment was that of the striping mutation in the California kingsnake, and then only on a rudimentary level. However, in the bulk of the produced hybrids, the patterns were consistent and essentially revolved around the common pattern of banding. Particularly in the instance of the tan-colored hybrids, the patterns consisted of essentially concentric rings around the body alternating with black, white, and some form of red coloration. As is demonstrated by Figure 14, these hybrids, while made up of differing parental species, resulted in animals that were very similar overall.

View of hybridization by evolutionists

Instances of proven hybridizations are often negated by evolutionists who dismiss the incidents out of hand by saying that they are sterile, were artificially induced, do not represent the evolutionary direction of an entire population, etc. Remarkably, this makes hybridization an acceptable aberrancy: something that allows the evolutionist to dismiss hybridization. It is convenient that this behavior can be so quickly dismissed by simply attributing the behavior to individual choice. Williams (1988) compares the concept of a species to an individual. According to him, species are individuals and individuals evolve, but a class does not evolve. This effectively allows hybridization to be interpreted as a tool for evolution because species are analogous to individuals who can and often do participate in hybridization for whatever reason.

Bessey (1908) makes a similar statement when he says that

> nature produces individuals and nothing more …. Species have no actual existence in nature. They are mental concepts and nothing more … and have been invented in order that we may refer to great numbers of individuals collectively.

In a sense, this statement can almost be seen as contrary to evolutionary theory. If nature only produces individuals, then how can evolution be working towards any kind of goal if all of the individuals are busy making up their own minds as to which direction they shall proceed. If indeed individuals are the driving force in nature, then hybridization should be accepted as a necessary practice by individuals who will eventually join the collective of the species' evolution.

Concept of species and hence baramins (kinds)

Of course, a prominent definition of a species is a group of individuals isolated from other populations that still possess the ability to interbreed. While this definition has recently begun to be redefined, the spirit of the concept still exists for the most part. Barton and Hewitt (1989) state that the species concept is based on the clustering of particular phenotypes that remains stable despite the possible invasion by foreign genes. The interesting thing about this definition is that it can essentially be revised to allow and encompass any new discovery or analysis of different species whether they are separated or merged.

Similarly, the creationist must determine exactly what the species concept means to him. Instead of defining separation as a guideline, the baraminic methodology is more inclusive. Whereas the baramin is the basic type of plant or animal as they appeared from the hand of the creator, we have refined our definition to allow for the expression of variation and thus speciation as being innate to the creation instead of supplemental to the creation. This has led to the defining of holobaramins and monobaramins for delineation of the natural world. Holobaramins, which are believed to number in the several thousands, represent a complete phylogenetic tree that is surrounded by discontinuity but not divided by it. A holobaramin has definable characteristics that are shared by its members, yet distinguish it from others. It is most analogous to Family, while the term monobaramin has been coined to refer to genus (Wise, 1992).

Conclusions

In this study, snake hybridizations between species and genera were made. In fact, the extent to which multiple species of snakes can interbreed and produce viable offspring were much more extensive than had been anticipated.

The findings of this study can easily be explained by both the evolutionist and the creationist. However, the integration of hybridization data into each of the respective scientist's framework can only be approached from dramatically different sides. Whereas the ability of reptiles to hybridize was dismissed by the evolutionist as chance encounters by rogue individuals unconcerned with the integrity of the species, the creationist can instead embrace hybridization and incorporate its existence into his explanation of the Creator's divine plan. Furthermore, the occurrence of successful hybridization closely fits the creationist model as opposed to the evolutionist model.

The rates of fecundity or hatchability witnessed in this study clearly point toward the idea that as a created kind, the snake baramin is encouraged to adapt and change by making use of as many successful alleles as possible. Higher hatching percentages were achieved between so-called distantly related animals than were achieved between snakes with identical genetic makeups.

Initial crosses were in the 70% success range, and although backcrosses were relatively high, at 85%, F1×F1 crosses lingered around 40%. So there was a barrier that inhibited speciation while still encouraging hybridization. By having a relatively low viability rate between F1 hybrids, this decreased the chances of these individuals separating from the group, exploiting new ecological niches, and speciating. Instead what seemed to happen was that these individuals hybridized and their offspring regathered these available genes to the gene pool of the kind as a whole, which allowed for the occasional influx of unique genes (alleles?) to make the population better able to adapt. This process can be allowed without any dramatic phenotypic change in the population as it was shown in this study that F2 offspring with 75% of the original genetic material were essentially indistinguishable from those members with 100% of the original genes.

To address the fear of many evolutionists regarding hybrids as being "supersnakes," it is perfectly understandable that they would view it as a muddying of the genetic waters because it eliminates speciation, something that they require to help evolution take place. If animals don't speciate, they can't change enough to develop into new organisms. Evolutionists fear hybridization because they see it as a merging of two already divergent branches of the evolutionary tree when in actuality what is occurring is that the animals are merely adapting along the same branch.

Essentially these snakes are "supersnakes" because they can exploit much more of the environment in order to succeed. We know that a variety of species already do this because of the abundance of hybrid zones where species ranges overlap. This allows for adaptation over a much larger area, thus opening up additional possibilities as far as habitat, food, etc., thus making the species more stable as a result.

Finally, the apparent homology between the loci of tyrosinase-negative amelanism in *Lampropeltis* and *Elaphe* needs to be addressed. It was remarkable that two species that are so distantly related developed the same mutation at the same locus, in reality, this fact merely supports the additional findings regarding the ability of the two species to interbreed. In other words, if they are related closely enough to produce viable offspring, then it only makes sense that they would also have similar mutations, because they are, after all, members of the same created holobaramins.

Suggestions for Future Research

There are several directions future research could take on the subject of snake hybridizations. It would be necessary to replicate the breedings between F1×F1 hybrids several times to determine if in fact they routinely show a low rate of viability. Should breedings among all first generation hybrids remain consistently low, speciation along separate branches of the phylogenetic tree should be discouraged in favor of the return of former alleles to the snake population as a whole.

Also, much knowledge could be gained by simply increasing the breeding pool of species that are examined. Testing other species and genera will help to delimit exactly what constitutes the individual holobaramins. Hybridization of *Pituophis*, *Bogertophis*, *Drymarchon,* etc. should be explored on a larger scale.

Finally, another potential benefit of hybridization studies could come from bridging the gap between egg-laying and live-bearing reptiles. It has already been demonstrated that, within the same genera, live-bearing and egg-laying lizards can hybridize successfully. Unfortunately, there are no snakes classified in the same genera with differences in birthing of young. As such, there would have to be some trials of intergeneric hybridizations between differing methods of birthing. This seems like it would be a rather dramatic leap to take that might not even be possible. It would, however, be necessary in order to delimit the boundaries of each of the created snake holobaramins. It is possible that live-bearing snakes are members of a different holobaramin than egg-layers. The first step in such an examination might be to work on the hybridizations between livebearers.

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