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Deciphering the Galaxy Guppy phenotype

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Abstract. Animal breeding hobbyists have been useful to science because they identify and isolate color coat mutations that geneticists can in turn use in their studies of the development and differentiation of color cells. This paper discusses a very interesting color mutant, the Japanese Galaxy, tracing its creation from back to a self-educated genetics hobbyist, Hoskiki Tsutsui. The paper discusses a constituent gene previously studied by Dr. Violet Phang, the snakeskin gene (the linked body and fin genes Ssb and Sst). And it discusses a gene previously unknown to science, the Schimmelpfennig Platinum gene (Sc). Through crossing experiments, the author determines that the combination of these two genes produces an intermediate phenotype, the Medusa. Incorporating the Grass (Gr, another gene unknown to science) gene into the Medusa through a crossover produces the Galaxy phenotype. Microscope studies of the snakeskin pattern in Galaxies and snakeskins reveals some parallels with similar studies made of the Zebrafish Danio.
Key Words: Galaxy Guppy, snakeskin, Schimmlepfennig, Medusa, Zebrafish.

Introduction. The first link between the science of genetics made by animal hobbyists can be traced back to Ms. Abbie Lathrop, a retired schoolteacher who supplied many of the mice with coat color color mutations to local universities in the northeast U.S.A. from her farm in Granby, Massachusetts (Eisen 2005). Many of the strains she bred originated from Japan where mice had been domesticated for centuries. The guppy hobby has the same potential to provide contemporary researchers with color mutants that have been identified and isolated by hobbyists (Păsărin 2010; Petrescu-Mag & Petrescu-Mag 2010; Petrescu-Mag et al 2010; Shaddock 2010b). This paper explores one of those mutants, a domestic strain of guppies called the "Galaxy." This guppy strain repeats history since it originated in Japan and made its way to Europe and North America through the guppy hobby trade.

Several years ago, I set out to determine the genotype of this strain (Figure 1) by recreating it from its purported base strains. My quest to recreate the Tsutsui Japanese Galaxy from the constituent genes turned out to be a challenging task full of twists and turns. And the tale of the journey is a good study in the trials of hobbyist guppy genetics.

Figure 1. Japanese Blue Galaxy. Picture by Luke Roebuck. This Blue Galaxy incorporates the Japanese Grass and Asian Blau genes into the Galaxy genotype.

Part of the problem is in the nomenclature. The Galaxy is a guppy that has a coarse snakeskin pattern that is also found on many different strains of guppies, including guppies some call cobras. Since there is no widely accepted registry of strains on the Internet and nobody but me has been foolish enough to attempt to publish one (in the online Guppy Strains Wiki and my Guppy Color Strains book, Shaddock 2010a), there is lots of room for argument. People get really upset over names, as abortive attempts to change the names of mountains or streets attest.

I knew that if I would be able to create a Galaxy phenotype from its constituent genes then I would be in a much better position to judge whether a guppy was a true Tsutsui Galaxy or a look alike. So I decided to undertake the project.

I'll provide a case history of the process that I went through, which is a combination of scientific research, Internet research, genetic analysis, microscope and DSLR (Digital SLR, i.e. a digital camera with interchangeable lens) image study and even linguistic analysis.

Does the Galaxy Exist? Of course the first question you have to address is whether or not there is such a thing as a true breeding strain called Galaxy. As far as I know there are no verified inbred descendants of the original male Galaxy developed by the original breeder. There are many guppies that people post on the Internet as Galaxies, and guppy sellers advertise snakeskin-like guppies as Galaxies.

There is lots of room for error. The person who gave the Galaxy its name was the Japanese breeder Yoshiki Tsutsui, the famous guppy breeder and hobbyist guppy geneticist.

Around 2002 I was in correspondence with him about the origins of the Galaxy. But it was difficult because his English was bad and my Japanese was non-existent. I never got a chance to further question him about the origins of the Galaxy guppy after that initial contact. Tsutsui died of a stroke.

Tsutsui told me that the Galaxy was a combination of the snakeskin and platinum genes. He said that there was another very similar phenotype called the "Medusa" that was created in Japan. The caudal fin was different. Here is a picture (Figure 2) of a Medusa provided to me by Stefano Bressan.

Figure 2. Medusa by Stefano Bressan. Notice the strange colors and patterns of the caudal fin. This is the classic Medusa trademark.

In an interview on a guppy site Tsutsui said his Galaxy was created out of the Schimmelpfennig Sword and Snakeskin Lace strains. One individual in a drop showed a crossover of the genes to the Y chromosome. Subsequently he crossed into an X-linked Grass guppy to improve the fins.

I looked throughout the Tsutsui website and only found one picture labeled with the term "Galaxy." It was a cross between a Galaxy and a Grass Guppy. He called it a Blue Galaxy Grass (Figure 3).

Figure 3. Tsutsui's Blue Galaxy Grass.

Notice the way the body is divided horizontally between the yellow Schimmelpfennig platinum yellow color and the snake dotted pattern. I will come back to this later. This is the authentic original Tsutsui Galaxy as he meant it to be. It is a "Blue" Galaxy because it incorporates the Asian Blau gene (see details about Asian Blau in Shaddock 2009).

Now I will go to the best secondary evidence I have. It is a picture sent to me by Luke Roebuck of a Japanese Blue Grass (Figure 4).

Figure 4. Blue Galaxy. Picture by Luke Roebuck.

I had this strain in 2002 and created a Moscow variant from a cross with it. There is a white version of this strain. It was developed by the Canadian breeder Uwe Bergman, who got the Blue Galaxy strain from Luke (Figure 5).

Figure 5. White Galaxy. Guppy and picture by Uwe Bergman.

Uwe's version is similar to Tsutsui's original. Luke got the strain from Japan. So I am reasonably sure that the Galaxy pictures above can act as a reliable guide to the Tsutsui Galaxy phenotype.

Eddie Lee on a visit to Japan took a picture of a Hitwari Yellow Grass Galaxy. Once again I note the blue bandit marking (Figure 6).

Figure 6. Hitwari Yellow Grass Galaxy. Eddie Lee photo.

In all the examples of Galaxies so far you see a distinct blue patch in the front of the body, the so-called bandit marking. I consider this to be a key characteristic of the Japanese Galaxy for reasons I provide below.

Identifying the Galaxy Phenotype. What are the common features of the different Galaxy pictures?

Coarse Snakeskin Pattern. The Japanese Blue Galaxy shown in Figure 1 expresses a coarse snakeskin pattern. Other galaxies show a somewhat dotted pattern.

Vertical Bands in the Peduncle. In all six examples there is a distinct vertical orientation to the snakeskin pattern in the peduncle. I have seen guppies without the vertical bands called Galaxies, and I have seen guppies with vertical bands in the peduncle called "cobras." There is obviously a blurred boundary between very similar phenotypes. The vertical bars are often treated as the result of a single gene. But as I pointed out in the snakeskin chapter, the vertical pattern in the peduncle may not be due to a gene separate from the snakeskin complex of genes. It may be the result of the interactions of existing genes. I will produce evidence of that below.

Bandit Markings. There is a large blue area in the front of the body, the bandit marking. I think this is indeed the defining trademark of the classic Tsutsui Galaxy. In fact this may be the trait that sets the Galaxy apart from cobra snakeskins that look like Galaxies. My guess is that it is in fact the expression of the Schimmelpfennig Platinum Sword trait, expressed as yellow platinum on the original parental strain, but as dark blue to black on the hybrid. It is a kind of marker for the Schimmelpfennig Platinum (Sc) gene. Without the Sc and snakeskin genes, the guppy cannot be a Galaxy.

Spotted Fins. Cesar Zapata, a member of Guppy Designer, made a very interesting observation about Galaxy phenotypes on the Guppy Designer forum. He said he though Tsutsui named his strain "Galaxy" because of the dotted pattern on the fins. Indeed Tsutsui had told me he named the guppy after the stars in the sky. The fact he would choose the dotted pattern of the caudal fin as the defining characteristic of the strain is consistent with naming conventions for show guppies, which take the caudal tail and color as the basis for the guppy's classification.

The spotted fins distinguish the Galaxy from the Medusa, which would be another reason why Tsutsui named his strain after its fin pattern. The medusa caudal fin is a mosaic of colors and patterns.

Spotted Belly. It is also possible that the dotted pattern on the belly area you see in the Tsutsui Blue Galaxy is a distinctive feature of the original version of the strain. I am not absolutely sure about this.

What makes hobbyist guppy genetics so difficult is the lack of a truly international standard for naming guppies. How can I be certain that what I describe as a Galaxy phenotype would be broadly accepted as a description of this phenotype?

The only way to validate the information would be to recreate the strain from the founding strains identified by Tsutsui. But even this is problematic, since we cannot be certain of these original founding strains.

Identifying the Lace Phenotype. The Tsutsui recipe for a Galaxy calls for the use of a "lace" snakeskin. How could I be sure of using the same type of snakeskin as Tsutsui?

The word "lace" is another one of those hobbyist terms that has different meanings around the world. The hobby lacks a global registry of names that everybody agrees on, so I will had to risk being wrong about Tsutsui's use of the term.

First some background. It is interesting to note that the term "lace" was applied to the very first snakeskins. We actually have a picture of the C.W. Phillips lace guppies (Figure 7) (see the interview conducted by James Kelly in the *Tropical Fish Hobbyist* magazine in 1964).

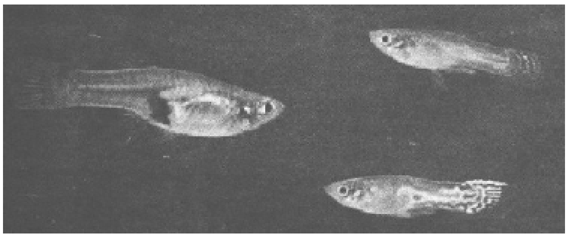

Figure 7. Phillips Lace Guppies. Image provided courtesy Luke Roebuck.

Some people suggest that since Phillips first used the term lace, we should respect his usage. But if you look at the Phillips guppy, you will see it has a primitive and rather crude pattern. Obviously he was referring to the way the snakeskin pattern resembles the pattern of lace. In fact today the term "snakeskin" would probably be used to describe the pattern on the Phillips lace today. Few people would now describe the pattern as lace. Sorry Mr. Phillips.

However, as the pattern was developed through outcrossing and selective breeding over the years, the term "lace" eventually became more restricted in its meaning to a much finer pattern, like the one seen on Figure 14 below.

Recently I realized that Asians tend to call a snakeskin with a very large pattern a "cobra" snakeskin. I had assumed that guppies with vertical bar patterns in their peduncle were cobras because the cobra snake reptile often has bars. What the hobby needs is an international registry of names! That would take about four years of heated debate!

In point of fact the snakeskin pattern is an example of a trait with continuous variation, meaning it can vary between a coarse pattern and a very fine pattern. When you see a continuous varying trait you can assume it is due to multiple genes, not a single gene. That is why it is so difficult to distinguish between a lace, a cobra, a coarse snakeskin, or whatever term people will try to use to describe a pattern.

So even if an international body managed to hammer out a definition of lace, there would still be a problem in applying it to a phenotype that is half-way between a coarse and fine pattern.

A further complication is the fact that the snakeskin body and fins can be due to separate gene, which makes guppies with snakeskin bodies and solid fins possible. This has led to some people claiming that the term "lace" should only be applied to guppies that have a lace pattern on the caudal fin.

This is of no practical value to the biologist or geneticist. It only has value is to a guppy show judge who must determine if a guppy is allowed to compete in a specified class or not. To argue that a biologist should not use the term lace to describe a finely detailed pattern on the body of a guppy with crude pattern fins is to mix the world of genetics up with the world of show guppies. I suspect this is the reason why scientific names are so long, difficult to pronounce and rarely used in daily conversations.

But we still have to understand how Tsutsui used the term. German breeders use the term "filigree" (German for "lace") to describe lace guppies like the one in Figure 14 below. Tsutsui, who was a great fan of German guppies and a friend of German breeders, would have used the term lace to describe the lace guppy in Figure 14. Since the guppy in Figure 14 is actually from Germany and is described as a "German Lace" guppy, we can be reasonably sure that we are using the same guppy genotype as Tsutsui.

The final proof that will establish that I am interpreting the term correctly will be if my cross between the Y-linked Schimmelpfennig Platinum Sword and the Kaden X-linked Lace Snakeskin actually produces a Tsutsui Galaxy. You will have to wait until the end of the chapter to see for yourself if I succeeded. At that point it won't matter what we call the guppy in Figure 14, will it?

Identifying the Platinum Phenotype. Tsutsui told me that he had used a platinum strain to create the Galaxy.

Tsutsui often talked about the platinum gene in his work and in the genotypes he assigned to various strains. If I am not mistaken, he thought there was a single platinum gene found in many modern guppy strains, including the Galaxy, Medusa and such broad types as the Full Gold guppies, Santa Marias and so on.

But in attempting to reproduce his strain I discovered that there are at the very least two different "platinum" genes or gene complexes. It was my attempt to recreate the Galaxy using what Asians call the "Full Platinum" strain (Figure 8) that led me to this discovery.

Figure 8. Albino Full Gold Leucophore. Philip Shaddock

I crossed this guppy with an X-linked snakeskin and did not get anything close to a Galaxy or Medusa phenotype. Eventually I was able to determine that the yellow platinum color found in the "Full Platinum" was in fact a gene I call the "metallic gold" gene. I had incorrectly assumed that the Full Platinum contained the same gene as the strain Tsutsui had used to create the Galaxy, and which the unknown originator of the Medusa had used to create that strain. But I further compounded my error by using the wrong type of snakeskin guppy!

I used a guppy that is best described as a Yellow Cobra snakeskin (Figure 9).

Figure 9. Yellow Cobra Snakeskin.

Now compare this snakeskin to the Galaxy pictures I showed you earlier. It has some of the traits I early ascribed to the Galaxy, including the vertical bars in the peduncle, and the spotted fins. It does not appear to have the bluish bandit marking, but rather a yellow metallic color in the same area.

I do not know the genotype of the Yellow Cobra strain other than knowing that it is X-linked snakeskin. Take a look at a similar phenotype found in Europe (Figure 10).

Figure 10. Doublesword Snakeskin. Photo by Finn Bindeballe from the Dansk Guppy Club, fall 2007.

This is essentially the same phenotype, with more obvious bandit markings in the front of the body. Is it a snakeskin or a Galaxy? I think most Europeans would call it a snakeskin or cobra snakeskin.

Now let's take a look at another phenotype (Figure 11).

Figure 11. Metal Head Stoerzbach Snakeskin. Result of a cross between a Moscow male and the X-linked Yellow Cobra Snakeskin shown earlier.

Looks somewhat similar to the Galaxy phenotype, does it not?

I happen to know it is a cross between a Moscow male with the Stoerzbach gene and the Yellow Cobra Snakeskin strain I showed earlier.

Is this a Galaxy phenotype?

I think what I have demonstrated here is the well known caveat in genetics research that a similar phenotype can have quite different genotypes.

Or does it?

I actually think that the Yellow Cobra Snakeskin has at least some of the same snakeskin genes as the Galaxy. Curiously the Yellow Cobra has a lot of yellow platinum color in the front of the body. Is this an allele of the Schimmelpfennig Platinum gene? I think it might be. So it may be the case that I had a guppy in my fish room that had the basic Galaxy genotype... it just had a different platinum allele.

In actual fact there is a whole range of crosses between snakeskins and other strains that might look vaguely like the original Tsutsui strain. Take a look at the Santa Maria guppy (Figure 12).

Figure 12. Picture of Santa Maria provided to me by Yours Young.

The Santa Maria looks very similar to the Galaxy, when you check it against the defining criteria. The big difference is in the fins, which are mosaic in the case of this particular strain of Santa Maria. The bandit marking appears to be bigger as well. But again this might be the difference in one or two alleles. The basic genes involved in the phenotype might be the same.

Tsutsui says that the navy or dark blue large horizontal area in the front of the body distinguishes this guppy as a Santa Maria.

I think a lot of snakeskin lines have a "racing stripe" that extends from the eye back towards the dorsal, in the same position as the Santa Maria trademark.

In one of his books Tsutsui does an extensive treatise on the various different combinations of the snakeskin, platinum and Stoerzbach metal genes. The Santa Maria is a combination of the Stoerzbach metal, snakeskin and platinum genes. If it is indeed the case that the Santa Maria incorporates the Stoerzbach gene, then we may view it as a "metal Galaxy."

My attempt to create the Galaxy phenotype out of a cross between a so-called albino Full Platinum and a Yellow Cobra snakeskin did not result in complete failure. I did discover and document the Full Gold gene which I call the "metallic gold" gene. And a grey version of the Full Gold guppy resulted from the cross. Exploration based research does have its benefits...

But I would not rest until I had nailed the genotype for the Galaxy. So I decided to do more research.

The Correct Cross. It was a year into my research into the Galaxy before I finally determined that I had to find the actual strains used by Tsutsui and test cross them.

So I imported a Schimmelpfennig (Schimmelpfennig Platinum Sword) from a breeder in Hawaii, Daryl Tsutsui (not related to Yoshiki Tsutsui). And I imported a German lace snakeskin from Luke Roebuck in California.

Would a simple combination of these two strains produce a Galaxy phenotype in the F1 generation? I was not sure. The European guppies that came out of the cross looked like Medusas to me. I have never actually seen a Japanese Galaxy come out of the European recipe for the Galaxy.

With that said, the Schimmelpfennig that Tsutsui used in his original cross came from Europe I believe, so there was a common factor between European so-called Galaxies (which I believe are actually Medusas) and Japanese true Galaxies.

The Schimmelpfennig I got from Hawaii is the one shown in Figure 13.

Figure 13. Schimelpfennig Platinum Sword from Daryl Tsutsui in Hawaii.

The snakeskin sourced from Luke Roebuck was called a Kaden Lace Snakeskin and looks like Figure 14. I don't have a picture of the female, but she showed the snakeskin pattern in her fins.

Figure 14. Kaden Lace Snakeskin.

The F1 Males at 5 Weeks. At five weeks of age the fry showed signs of developing the Medusa phenotype (Figure 15). This male was particularly yellow, which comes across to some extent in the photo.

Figure 15. F1 Male at 5 weeks of age.

The female appears to be colorless at this point (Figure 16).

Figure 16. F1 Male and female.

I call this the Medusa phenotype because it lacks two key features of the Galaxy, the spotted fins and the bandit blue markings.

Figure 17. Another male catching the light at a different angle, showing the blue metallic color.

Finally one more image for good measure (Figure 18).

Figure 18. Another shot. Notice the bluish color in the area on the guppy's "back" and around the gills.

There are bars in the peduncle. Where did they come from? Some people would say that the snakeskin or the Schimmelpfennigs had a bar gene of some form. But I think there is another origin for the pattern, which I will show you in a moment.

The dorsal fin is starting to show a dotted pattern. If you look at the fins of the Schimmelpfennig father you will see that they are dotted. Some would say that the spotted pattern is due to a gene. I think they would be partially right, again for reasons I will give below.

Another observation is that the guppy appears to be divided horizontally, with the ventral a different pattern than the dorsal. We have see this in the half-tuxedo. It's almost as if the Schimmelpfennig gene were dominant in the top half and the snake in the bottom half. Look back at Figure 3. This is what we find in the Tsutsui Galaxy.

Finally notice that F1 males seem to have inherited yellow and white streaks at the bottom and top of their caudal fins. Will they develop swords? I thought I would have to wait until they matured to find out. But the answer came sooner than I thought.

Junichi Ito's Parallel Cross. Just after I wrote about the cross in a Design Lab article on the books site my friend Junichi Ito wrote me to tell me he had conducted the same cross, a Schimmelpfennig with a snakeskin. Even better, he provided pictures of the result of the cross (Figure 19).

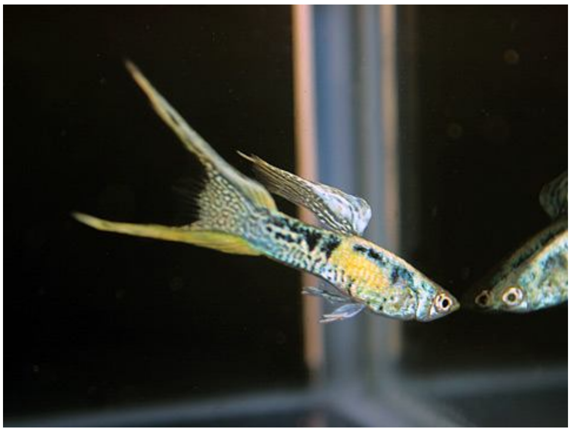

Figure 19. Result of the same cross by Junichi Ito.

At first I was crestfallen when I saw this picture. I wrote to Junichi, hoping to hear him reply that it was a Galaxy. "Is it a Galaxy?" I asked him.

"This is not a Galaxy." He replied, his answer in bold type. "***It is in a word, Medusa sword."***

The emphasis is Junichi's.

There are some striking similarities between this male and my juveniles. There seems to be a division of the body pattern between the top of the guppy and the bottom. And my juveniles seem to be developing swords.

The point of difference is that my juveniles have a bar pattern showing in the peduncle. And the snakeskin pattern in the lower part of the body is different.

Thwarted. That's the word that came to my mind when I thought about this latest outcome of my two year quest to build a Galaxy.

I was ready to declare at least a small victory in my quest to crack the genetic code of the Galaxy, when suddenly Junichi's description of the phenotype twigged my memory.

It was the European Schimmelpfennig crosses. Like Figure 20 and Figure 21.

Figure 20. Picture by Karen Koomans.

Figure 21. Picture by Hans Peter Neuse.

And then it struck me.

The recipe for creating a Galaxy (cross a Schimmelpfennig male to an X-linked lace female) is actually the recipe for creating a Medusa.

Here is the genetic code for the Medusa phenotype produced in the F1 of the Schimmelpfennig X lace cross.

$X^{La\ Ssb\ Sst}Y^{Sc}$, where:
La = lace, Ssb = snakeskin body, Sst = snakeskin fins, and Sc = Schimmelpfennig Platinum.

The German guppy pundit Claus Osche had told me that this recipe produced a Galaxy in the F1 generation, and I had responded by telling him Tsutsui had told me that a crossover event was necessary for the creation of the Galaxy. Claus countered that all that meant was that the strain became fixed by incorporating all the necessary genes on the Y chromosome.

As it turns out Tsutsui in the Guppylabs website interview said that he used a cross to a Grass guppy to improve the fins on his Galaxy. That is what set it apart. And he would have produced a true breeding strain. So there had to be a crossover. There is only room for one X chromosome on the male, and if that was the Grass gene, then the Schimmelpfennig and Lace genes needed to unite on the Y chromosome to make room for the Grass gene on the X chromosome.

Is this what Tsutsui meant when he told me there had to be a crossover, and he it took two years for the cross over to occur? I think that must be the case, because the basic Medusa phenotype is easy to create. Tsutsui wanted to perfect the Medusa by improving its fin shape with the Grass gene.

The Calico Snakeskin. I don't think I would have made progress in cracking the solution to the problem if I had not explored the lace snakeskin phenotype under a microscope.

The fact that my microscope studies came into play shows that the solutions to problems in practical guppy genetics usually comes from a variety of sources. And sometimes the clue is at the end of your nose literally... in this case.

The Fins. Let's begin with the fins. The dotted pattern on the Galaxy fins can be described as islands of melanophores on a sea of platinum. At first glance this does not seem to describe the pattern on the lace snakeskin's caudal fin (Figure 22).

Figure 22. DSLR camera image of the caudal fin of a lace snakeskin.

But you see the pattern differently under the microscope. Here is an image at 40x magnification (Figure 23).

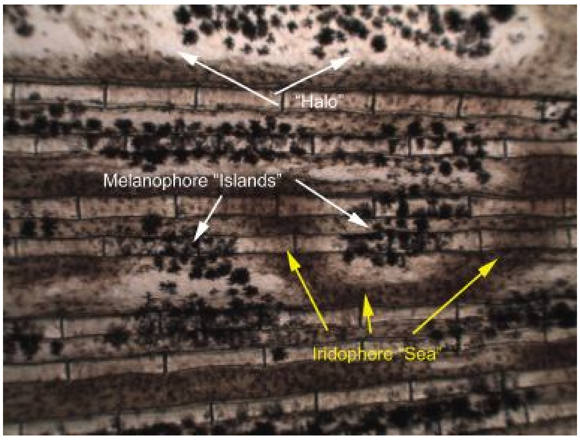

Figure 23. Image of a small area of the fin at 40x.

As you can see the black color cells form islands. This is consistent with what I discovered in my microscope studies years ago when I studied other snakeskin strains.

The dark area flowing in and around the melanophore islands is a mass of iridophores, the highly reflective yellow platinum color you see in the DSLR camera image.

There is a peculiar "halo" around the islands of black melanophores separating them from the yellow sea of platinum. It's a kind of no man's land. It seems that the color cells in the two areas repulse each other and the large black melanophores seem to clump together whereas the iridophores are spread out around them, like the sea around islands. The no man's area is like a beach.

In the crude snakeskin, the islands are bigger and the spaces between the islands are larger. In the Galaxy the same basic plan is still at work. It just creates a very large dot pattern.

The lace melanophore islands appear to be long and narrow not round and some of them appear to run into each other. But the basic plan is the same. There are melanophore islands in a sea of platinum.

The implication is that there is actually little fundamental difference between coarse and lace patterns. The lace is just a finer, tighter snakeskin pattern.

There is another case where the snakeskin chain link pattern is modified into a dot pattern. That is the case where a snakeskin guppy has been crossed with a half-black guppy. The cross produces what is called a Leopard guppy, named after the spotted fins (Figure 24).

Figure 24. Leopard guppy.

Here is what I think. I think the spotted fins on the Galaxy are the expression of the snakeskin lace pattern in the fins when it is modified by the Schimmelpfennig gene or genes. In other words, the spotted fins on the Galaxy are due to the snakeskin gene or genes.

If this is the case, why does the Medusa not have spotted fins? Actually it does, if you look closely at Junichi's F1 male. In the center of the caudal fin, in the area that is clear on the male Schimmelpfennig parent, the lace pattern emerges. In the sword extensions, the Schimmelpfennig yellow swords are expressed. In other words, the F1 male expresses both the Schimmelpfennig and lace pattern traits. Why they are not mixed, why they are separated is the mystery we must solve.

The same can be said about the body. If you look at my young F1 male from the cross and Junichi's male you see something remarkable. The lace pattern from the lace mother is expressed in the bottom half of the body, whereas the Schimmelpfennig pattern is expressed in the top half of the body.

When I first encountered this strange combination of the Schimmelpfennig and snakeskin traits I immediately thought of the Calico or Tortoiseshell cat that exhibits this same patch quilt pattern (Figure 25).

Figure 25. A calico cat. Credits to wikipedia.

The calico pattern is the expression of two different color alleles. The two alleles of the "o" gene are O - orange and o - black, referring to whether the melanin expressed is eumelanin (o) or phaeomelanin (O).

I known the same biological mechanism is NOT at work. In the case of the cat, the calico (or tortoiseshell) phenotype is due to the fact that X-inactivation normally occurs at random in the melanoblasts as they migrate over the surface of the cat embryo. If the X^o chromosome is inactivated and the X^O chromosome is active, you get orange melanin in the clone of melanocytes derived from that ancestral melanoblast. And vice versa. So you get black spots and orange spots. In the tortoise shell cat, there are many small spots, and where 2 spots of the same color are found next to each other the effect is that of a larger spot. In the case of calico, there is a third gene, S - white spotting, s - no white spotting. The S gene (several alleles?) reduces the number of melanoblasts and the result is a small number of clones of melanocytes. Since the spots are fewer in number, they can spread out further (no cell to cell inhibition). The result is a few large spots instead of hundreds (or thousands) of small spots. Some large spots are orange and some are black depending upon which X-chromosome (and O allele) remained active. The white areas are lacking melanocytes. But as far as we know, there is no sex chromosome inactivation in fish (thanks to Dr. Richard Squire to this overview).

Obviously this cannot be the same mechanism as found on male guppies. But the phenotypes seem similar. Look at the tail in Stefano's Medusa (Figure 2). A central area of the fin has a completely different pattern than the rest of the fin. There is something in the way the Schimmelpfennig (Schimmelpfennig Platinum or Sc) and Lace alleles interact that creates a "calico" guppy.

What can be said is that the Shim trait is dominant in some areas of the body and the snakeskin trait is dominant in others.

The Schimmelpfennig trait is only dominant where you see yellow platinum color in the Schimmelpfennig Platinum Sword male. The platinum color is in the upper half of the body and in upper and lower parts of the caudal fin (see Figure 18). If you compare the F1 male in Figure 15 to the male parent in Figure 13, you will see that the Schimmelpfennig gene is dominant in the areas of the body where there is yellow platinum.

The snakeskin pattern is dominant in the areas of the body where there is no yellow platinum and vice versa.

But what about the coarseness of the snakeskin pattern and the fact there are bars in the peduncle?

Obviously a gene (or genes, Petrescu-Mag 2009) from the Schimmelpfennig Platinum Sword is somehow influencing the entire body, otherwise you should get lace snakeskin instead of coarse snakeskin in the areas of the body where the snakeskin pattern dominates.

In other words, you cannot have a lace Galaxy. I think there is a more accurate way of stating this, which is that you cannot have a lace pattern where the Schimmelpfennig Platinum Sword genes are expressed.

Why not? I believe that there are multiple genes involved in snakeskin genetics, and also Schimmelpfennig Platinum Sword genetics and I will soon show why. But first I want to show that the Galaxy coarse pattern and the snakeskin lace pattern are actually closely related. I will show that the snakeskin pattern is due to more than one gene, and the lace gene is one of them.

Microscopic Evidence. On the surface of things the lace pattern looks like it is due to a gene acting independently, that is segregating independently from the coarse snakeskin gene. I do not believe this is the case. I believe that the lace gene is acting as a modifier of the coarse snakeskin pattern.

There is something that may not be obvious when you look at the lace pattern of the peduncle (Figure 26), and I missed it at first. It becomes a lot more obvious when you look at a microscope image of the area (Figure 27).

Figure 26. Peduncle area of the lace snakeskin.

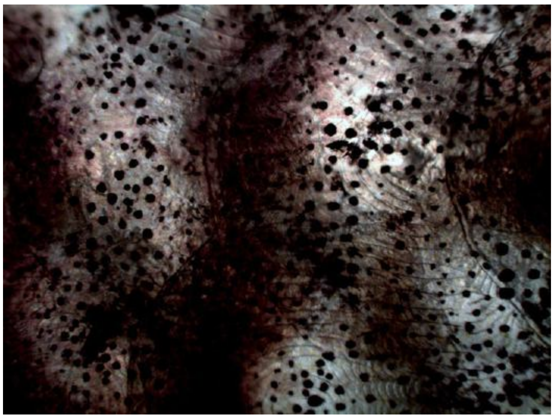

Figure 27. x40 Image of the peduncle under the microscope.

If you pan around on the peduncle under the microscope you notice that the light and dark areas form vertical stripes. Look at the DSLR image of the peduncle (Figure 26) and you will see that the pattern is largely vertical. In fact in a cross between a Stoerzbach Vienna Emerald Green male and the same X-linked lace strain as you see in Figure 25, I got young F1 males who had a coarse bar pattern in the peduncle, but later developed a lace pattern just like you see in Figure 26.

The fact that I got the lace pattern in the F1 of the outcross suggests that the lace gene is on the same chromosome as the snakeskin gene, the X chromosome. And the fact that some males started as coarse snakeskins with vertical bars and later developed into lace snakeskins (Figure 28) tells me that the lace gene acts as a modifier of the coarse snakeskin pattern, refining it.

Figure 28. The Stoerzbach Vienna Green male to X-linked snakeskin female produced both these F1 siblings, a coarse pattern snakeskin and a lace snakeskin. But the coarse snakeskin actually developed into a lace snakeskin as it matured.

In a cross between my X-linked Kaden snakeskins and a Vienna Emerald Green sword, I got lace snakes in the first generation of the cross. In a cross with the same Kaden X-linked snakeskins and a Schimmelpfennig Platinum Sword I got F1 and F2 males with a coarse snakeskin pattern and no lace. Why?

Obviously in the case of the Schimmelpfennig cross the lace modifier gene is being suppressed by a gene on the Y chromosome of the Schimmelpfennig male. This must be the reason why there are no lace Galaxies.

Maybe the Calico appearance of the Medusa is due to an analogous mechanism to X-inaction in mammals.

The lace gene (or rather its protein product) acts as a modifier of the snakeskin pattern and the Schimmelpfennig gene suppresses the expression of the lace gene. It causes the snakeskin pattern to form the peculiar "calico" pattern on the guppy. More specifically the Schimmelpfennig gene seems to vary its expression across the body. It produces vertical bars in the peduncle, a caudal tail divided into two zones of expression, as well as two zones in the upper and lower part of the front of the body (Figure 31).

I think this is due to the variability of the Schimmelpfennig gene's expression in different areas of the body (Figure 29).

Figure 29. Schimmelpfennig male without the Vienna Emerald Green pattern.

The F2 male in Figure 29 segregated out of a cross between a Schimmelpfennig Platinum sword and a Kaden X-linked snakeskin. Compare him to his Schimmelpfennig brother (Figure 30).

Figure 30. The Schimmelpfennig Platinum Sword phenotype.

The male in Figure 29 seems to have lost his Vienna Emerald Green traits. When you compare him to Figure 31, the blond Medusa phenotype, you can see that wherever there is yellow platinum there is no snakeskin pattern.

This includes the upper part of the front of the body and the yellow sword areas on the caudal fin. The half-body area seems to suggest the presence of a half-black gene, but we know that snakeskins cannot have the half-black gene (Shaddock 2008; Petrescu-Mag 2008), so this guppy cannot have the half-black gene.

The conclusion is that the Schimmelpfennig gene is expressed differently in different areas of the body. If you look at Figure 31, you can see that the Schimmelpfennig gene in place of the snakeskin gene where it is most strongly expressed (most yellow) and in the areas where it is weakly expressed the snakeskin gene is expressed. But it is expressed in a very crude manner.

Figure 31. Blond Medusa phenotype.

The fact that the snakeskin gene is expressed in a highly crude manner in the weak Schimmelpfennig areas is evidence, I think, for the fact that the Schimmelpfennig gene is a whole body gene (or genes!).

However, even many authors consider the snakeskin character as qualitative and not quantitative (see Lindholm & Breden 2002; Petrescu-Mag & Bourne 2008), I am sure that the coarse snakeskin pattern is composed of more than one gene, so it is possible that the Schimmelpfennig gene is in fact an allele of one of the snakeskin genes.

Backcross F1 to Kaden. Figure 32 is the phenotype that I from a backcross from a F1 male to the X-linked Kaden lace snakeskins.

Figure 32. The Medusa Phenotype at 5.5 months old.

You can see some red color at the bottom of the caudal fin, which started appearing at five months old. This is characteristic of the classic Japanese Medusa, as seen in Figure 2. Neither of the founding strains showed red in the caudal, so this must be do to a gene whose expression was suppressed in the founding strains.

Another notable feature is the increasing density of the snakeskin pattern in the peduncle and the spotted pattern on the caudal fin. The fact this was a backcross to the Kaden snakeskin line may be the reason for the presence of more snakeskin-like features.

Indeed this male's siblings have an even finer, almost lace-like pattern in the body (Figure 33).

Figure 33. Sibling to the male in the previous Figure.

At first it appeared that the siblings were lace phenotype, but if you look closely at the pattern in the peduncle you will see that it is still a vertical pattern. As I noted before, the lace pattern is implicit in the snakeskin pattern, and I have noticed that the Kaden Snakeskins tend to have distinct vertical bars in the peduncle when young, but these become more lace-like as they get older.

Finally notice the intense blue color at the base of the peduncle and the blue coast to the body. This is due to the EGI (Emerald Green Iridescent) gene found on one of the founding strains, the Kaden snakeskin.

Is this a Medusa guppy? I think the blue bandit mark in the front of the body seals the deal. It partially replaces the yellow platinum color of the F1 Medusas, and the caudal fin appears to be very close in pattern to the classic Japanese Medusa.

The yellow platinum color appears to be weaker and the blue color stronger in this backcross. It is well known in Zebrafish research (Odenthal et al 1996) that yellow color cells are necessary to the expression of the Zebrafish stripes. Altering the distribution of yellow color cells may in fact alter the expression of the snakeskin pattern in the guppy.

How do we transform this Medusa phenotype into a Galaxy phenotype? I plan to also do an outcross to a Japanese Blue Grass line to see if I can produce something closer to the Tsutsui Japanese Galaxy.

Galaxy and Medusa Variants. The F1 males from a cross between a Schimmelpfennig male and lace snakeskin female have calico bodies that are a mixture of Schimmelpfennig and snakeskin patches. Yet we see Medusas that have Galaxy bodies and "calico" fins. Why?

We know that the snakeskin pattern on the tail is under separate genetic control from the snakeskin pattern on the body.

This was confirmed when I studied the two patterns under the microscope and discovered they were composed of different color cell populations. It is also confirmed by the many types of snakeskins that are possible, some with snakeskin bodies and non-snakeksin fins, others with non-snakeskin bodies and snakeskin fins (Phang et al 1989ab, 1990; Phang & Fernando 1991).

I sometimes write the genetic code for snakeskins as:

$X^{Ssb\ Sst}$ Y, where: Ssb = snakeskin body; Sst = Snakeskin tail

The two genes are so close together on the same chromosome that many people never notice that they are separate genes.

If the lace gene tends to segregate with the snakeskin gene with a high frequency, this implies tight linkage and suggests the close proximity of the two genes.

Dr. Richard Squire (in private correspondence with Philip Shaddock) observes: "Ssb and Sst are probably descended from a single gene duplication event at some time in the past. But these two genes have undergone divergence, so that one effects the body and the other the tail (perhaps the ancestral gene affected both the body and the tail). These two genes are no longer alleles of each other. They are closely related but now different genes."

Conclusion. I think it is impossible to create a genuine Galaxy, "genuine" in the sense of a guppy with the identical genotype to the Galaxy guppies first created by Tsutsui. We simply do not know what the genotype of his founding strains was and do not know the genotype of the resulting phenotype chosen by Tsutsui and given the name "Galaxy."

We do know that you can create a crude or first-generation Galaxy type of guppy by crossing a guppy with the Schimmelpfennig Platinum gene (Sc) with a guppy with the snakeskin gene (Sst and Ssb). Whether or not a lace version of the snakeskin gene is required is open to question at this point. The lace gene or its product is probably a modifier of the coarse snakeskin gene, producing the lace phenotype. I suspect that the lace modifier is not required.

In all probability Tsutsui gave the name Galaxy to a Medusa phenotype that incorporated the Grass fin gene. Whether you start with an X-linked snakeskin and a Y-linked Schimmelpfennig gene or vice versa does not matter.

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