This kind of thing has always interested me. Because of the major differences in fish getting where they are, when it comes to genetics, you need to separate discussions on brookies and browns. For environmental issues, not so much.

Environmental: Age, sex, diet, time of year, physical surroundings all play a part. Red pigmentation is from keratin, which is found in heavy concentrations in crustaceans, especially crayfish and freshwater shrimp, but also scuds, and pretty low concentrations in "soft" bugs like caddis, mayflies, and the like. So this is largely from diet, though, even if they eat baitfish, it then depends on the baitfish diet. Basically it's stream specific that depends on the base of the food chain. You will see especially in bottom release tailwaters a lot of bright reds in all species of trout, due to an accumulation of freshwater shrimp in a large lake that gets concentrated when flushed out, and forms the base of the food chain.

Baitfish heavy diets tend to produce silvery fish, especially in lakes and large (non tailwater) rivers.

As for other colorations, yeah, I do think there's a bit of a chameleon effect, mostly due to sunlight. Fish in sun are brighter. Fish in dark forested streams are darker. Fish in deep water are paler.

Colors change with age too, but this is probably more a reflection of dietary changes as they age (other than losing the parr marks).

Heredity on browns:

Well, there are Loch Levin browns and German browns. German browns have lesser rounder black spots and also have the bright red spots. Loch Levin browns have more, and larger, more squarish black spots and a notable lack of red spots.

That's pretty well known, and reality is that PA browns are generally a combination of the two, with additional variations (both natural and manmade) which have occurred due to evolution and/or selective breeding. An important concept is WHEN a stream was "seeded". Back in the early 1900's, the logging boom knocked out a lot of trout streams, and they started stocking to replace them. Often fingerlings, and often browns. Generally these were German browns, and have formed the basis of your average PA wild brown trout. Both of your pics are decent examples. They don't appear to me to be that different genetically, but the differences here are more diet and sunlight based.

Over time, the PFBC has received fish from other states, mixed and matched them, and established it's own breed. They are more of the Loch Levin variety, but still a mix. At the same time, they were being bred to grow quickly, be less skittish, etc., and with these changes came some unintentional changes in appearance. When
these fish were stocked, they too seeded some streams, though to a lesser degree because the German browns were already established in a lot of places, and because the PFBC hatchery strain was becoming less suited to the wild. Nonetheless, even if they did not “seed” new populations very often, they did in some cases interbreed with wild populations and formed various hybrids, and most PA browns carry some of their genetics, to varying degrees. What shows through in a mix is complicated in genetics, as it’s possible for two German appearing browns to have a Loch Levin appearing offspring, just as two mutt dogs of the same litter can vary a lot. So there’s some randomness to it even within a stream. Still, the degree of which way it’s ancestry leans will determine the most common appearance in a given watershed.

Genetic brookies:

Brookies are native. They evolved here over thousands of years. Before the white man, it is likely that every individual stream held a unique genetic makeup. Streams close to one another were likely “seeded” by the same population. Hence, streams closer to one another had genetics closer to one another, while entirely different watersheds are more different. Even within a watershed, the degree of “mixing” due to fish movement probably varied wildly based on physical ease of movement, hence the uniqueness of each little stream depended on it’s isolation over thousands of years. Whether you call each stream a separate “strain” depends merely on how narrowly you want to define the term “strain”.

Anyway, during the logging boom, we lost a very high number of brook trout streams, and the ones that survived still took a hit. Once the forests re-grew, streams were re-seeded from nearby remaining populations, as well as from PFBC stockings. There may be “pure” heritage strains remaining, but they are rare. In most places, I suspect it’s a mish mash of nearby heritage strains combined with some stockie DNA from various ages thrown in for good measure (see the brown discussion). A lot of genetic work needs to be done here, and some of it is happening.

That’s not to say uniqueness is lost. I can’t, for instance, tell the difference between brookies in the various tribs to Pine Creek. But I seem to be able to have some luck telling the difference between brookies in the Allegheny, Susquehanna, and Delaware drainages. Based on pics, generally to about a 70% accuracy (which means I’m not good at it, but better than a random guess). I attribute it to the fairly significant differences between the heritage strains of those completely different drainage paths. And even today’s brookies have significant influence from those strains (even if they’re not “pure”).

Most of the differences I see aren’t coloration based (darker or lighter, degree of red on belly, etc.). But rather spot pattern based. Size and distribution of the YELLOW spots as well as the red. Your two pics I’d guess to be from the Susquehanna drainage. I’m basing that on the largish yellow spots that are few in number but don’t progress very low (high solid colored belly extending almost to the lateral line), and red spots generally found in nearly perfect horizontal lines, rather than randomized. Also, what appears to be no patterning on the tail. There are exceptions, but these are generally characteristics of Susquehanna based brookies.