HOW CROSSBILLS MAKE THEIR BILLS CROSS

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EVIDENCE FOR HOW RED CROSSBILLS MAKE THEIR BILLS CROSS

All crossbills in the genus, Loxia, in the finch family (Fringillidae) have permanently crossed bill tips to enable them to efficiently pry cone scales apart to remove seeds from evergreen cones with their dexterous tongue. There appeared to be no consensus or direct observations reported in the scientific literature as to how or when the bill tips on young crossbills become crossed. Consequently, the last three Red Crossbill (Loxia curvirostra) young I rehabilitated were regularly documented with photos until the tips of their bills were successfully crossed and the young birds were able to remove evergreen seeds from cones. Photos were taken of two uninjured siblings received in 2017, at intervals from the time of the late hatchling stage when they arrived for care, to after they had successfully made the tips of their bills cross. One received in 2008 was injured and unable to stand because of a broken leg. Photos show what happened to its bills when it was unable to twist its bill tips to make them cross.

The photos in this document are strong evidence for how and at what age the bill tips of young crossbills are made to cross by the bird's own behavior, as well as what happens to its bills when a bird is incapable of doing that behavior.

A hatchling Red Crossbill (I refer to as the dark RECR in the photos below) on April 13, 2017 showing its finch like bill, with the tip of the upper bill beginning to lengthen and turn down just slightly.

The two healthy crossbill youngsters began twisting their bills many times per day at approximately 29 to 30 days of age, by grasping small broken branches, knobs or other protrusions on branches on which they perched. The photos taken at various times during development show how the bill tips appeared on arrival for care, then during and after the fast growth period of the bill tips. The bill shape is clearly shown in the photos prior to and during the period of twisting, and immediately after the bill tips were permanently crossed. One of the young crossbills twisted the upper bill to the right and the lower bill to the left. The other twisted the upper bill to the left and the lower bill to the right.

When the period of fast bill tip growth began on the injured bird, the tip of the lower bill grew directly up into the bottom of the anterior of the upper bill forcing the bills apart**.** The bird had a broken leg and was lying in a nest of soft rags. It couldn't stand and twist its bill tips. I had to decide which way to make the upper bill go and taped the bills in a crossed position between feedings and at night, until the fast growth period of its bill tips was finished and the tips were permanently crossed.

Over the 50 plus years that I have rehabilitated birds, I received over 20 hatchling Red Crossbills and cared for them until they had made their bills cross and were ready for release. In my close observation of those post-fledgling crossbills, all except the one with the broken leg, which was lying in a nest of soft rags, actively twisted their bills to make them cross. Even one with an injured wing twisted on the low branches I furnished for it.

Several years ago, I reported observations by wildlife rehabilitators to ornithologists, concerning how post-fledgling Red Crossbills physically make their own bills cross. However, without the photographic evidence provided in this document, they were not convinced. Even with this photographic evidence, it has been difficult to persuade some people that the young crossbills themselves are actively involved in making their own bills cross while the bill tips are in the fast growth period. This document provides much more evidence for how the bills are crossed than any study I have found on crossbills in the scientific literature.

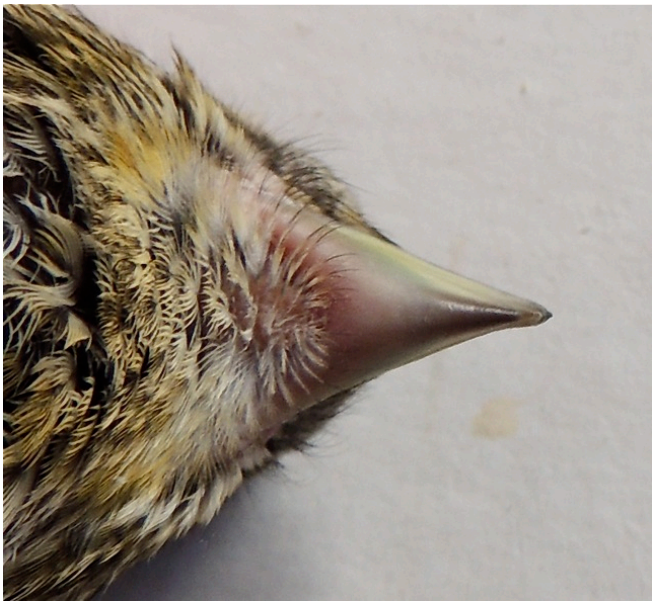
The bill of a young crossbill, after hatching and prior to the sudden growth of the bill tips, looks similar in shape to the bills of other youngsters in the finch family. This is shown on the Red Crossbill hatchling that is about 10 days old in the photo on page 1. The fingernail like covering, made of keratin, on the bills of most birds is called the rhamphotheca. About 8 to 10 days after young crossbills begin flying around with their parents after fledging, certain growth hormones produced by the pituitary gland are genetically programmed to activate. This hormone surge causes the young crossbills to have accelerated growth of the rhamphotheca at the tips of their bills. And similar triggers of gene expression likely cause the birds to begin the bill twisting behavior, which has to completely coincide with the sudden fast growth of the bill tips. However, I could not determine by close observation or photos why one bird would twist the lower bill to the left and the upper bill to the right and another bird (a sibling in the cases of hatchlings I raised) would twist its bills the opposite. Dr. Jamie M. Cornelius, Department of Integrative Biology, Oregon State University, Corvallis, Oregon suggested that the twisting direction by each individual bird may be directed by lateralization of their brain.

The pressure created by the biting/twisting behavior of the bird twisting on protuberances on branches actually bends the fast growing rhamphotheca and also bends the still somewhat malleable tips of the mandible bones the rhamphotheca covers in the direction the bird twists them. This was clearly shown in the photos of the bills after the bill tips had finished the fast growth period and the bill tips had been permanently crossed. **Without the twisting behavior the young birds do themselves, the bill tips and the mandible bones would remain straight.** This was proven by the injured bird's bill tips remaining perfectly straight, until I taped its bill into a crossed position and kept it taped, except when feeding it. The photos of that bird shows that if a young crossbill is not able to twist its own bill tips to make them cross, the bird's mouth will be forced open further and further by the fast growing lower bill tip pushing into the bottom of the upper bill. After three or so days of bill tip growth, the bird is not able to eat or drink and would soon die of dehydration or starvation. If that scenario had happened to all the young crossbills after crossbills split off from other finches well over two million years ago, there would be no crossbills here now to be observed or discussed.

It was suggested that perhaps the biting and twisting by the post fledgling crossbill youngsters is simply displaced desire to be foraging on cones and the crossing would have occurred without any behavior on the bird's part. When I raised hatchling crossbills, I put cones in the flight box with the fledged crossbills while I was still feeding them many times a day. Since they were not able to fly around with their parents and the other members of the flock and observe how to remove evergreen seeds, I wanted them to see and become use to cones. I never observed that any of the youngsters tried to remove seeds from the cones or saw any evidence that they paid any attention to the cones. After the bill tips had been twisted over and over, possibly close to a 1000 times a day and were permanently crossed, the birds stopped twisting on protuberances on branches. It usually took at least several hours for one of the youngsters to figure out how to remove the seeds from the Ponderosa Pine cones, after which the others quickly joined in removing the pine seeds. Apparently by watching the first little Einstein, they quickly determined how to use their bill tips to pry open the cone

scales and remove the pine seeds with their tongues. The crossbill post fledgling with the broken leg had flown around with its parents and other flock members prior to being injured. It immediately seemed to know how to pry the scales open and remove the pine seeds as soon as it could stand and walk on its healed leg and was put in a flight box with pine cones.

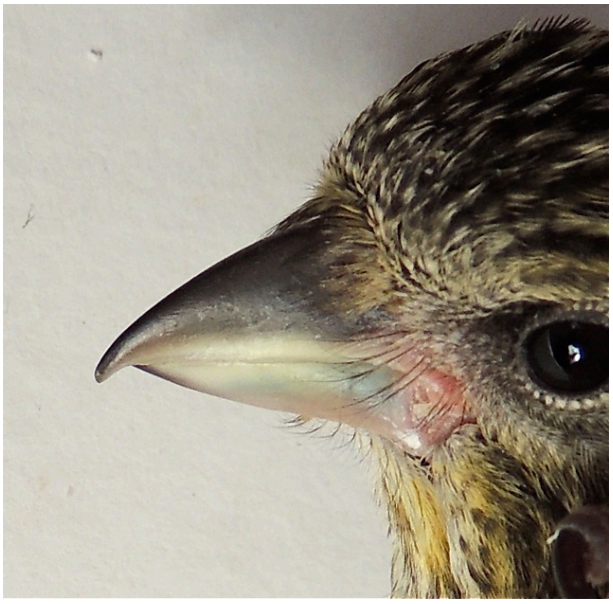

The bills of the same dark Red Crossbill shown on Page 1, photographed again on April 26, 2017, 2 weeks after the photo as a hatchling was taken. The dark Red Crossbill and its sibling were able to fly and were eating by themselves when the April 26 photos were taken. They were not quite 4 weeks old, depending on the exact day of hatching, which I calculated to be around April 3 or 4. These photos show its bills from the right side and from a bottom view. The upper bill had grown somewhat longer than in the photo on page 1, but there is no evidence of crossing or of which way the tip of the upper or the tip of the lower bill will go. Both bills appear to be aligned in a perfectly straight position and the bills have not yet begun the period of fast growth of the tips. This bird and its sibling were brought to me when their nest tree was cut down and the nest destroyed on April 13, 2017. This bird can be told from its sibling by the darker facial feathers, so is referred to as the dark RECR fledgling.

These are the same views of the above Red Crossbill's sibling also taken on April 26, 2017. This bird has lighter feathers around the eyes and on the face. It will be referred to as the light RECR fledgling. As on the dark RECR fledgling, the upper bill has grown somewhat longer than when it arrived for rehab, and is beginning to turn downward, but there is no evidence to indicate which way the upper or lower bill will go.

The photos on this page show four different views of the bills of the dark RECR fledgling on May 1, 2017, one week after the photos on page 3 were taken. These photos show both sides of the bills. The bills tips remain in a straight position, with no indication as to which side the lower and upper bills will go. On both bills, the length of the entire bill had visibly increased, as had the depth and width.

These photos show the bills of the dark RECR fledgling in a top view on the left and a bottom view on the right on May 1. The bills remained in a straightforward position and there is no evidence of crossing or of which way the bills will cross in any of the photos. The bills had not yet begun the fast growth of the tips, although the upper bill tip is slightly longer than it was the previous week on April 26, when the photos on page 3 were taken.

The photos on this page show the bills of the light RECR fledgling Red Crossbill, also taken on May 1, 2017. The above photos show both sides of the bills. The bills tips remain in a straightforward position, with no indication as to which side the lower and upper bill will go. Similar to its sibling, the length of the upper bill had increased slightly, as had the depth of the bills.


These photos show a top view on the left and a bottom view on the right. As on its sibling, there is still no evidence of crossing or of which way the lower and upper bill will go. Both bills appear to be perfectly straight and the bills have not yet begun the fast growth of the tips, although the upper bill tip is slightly longer than it was on April 26, shown in its photos on the bottom of page 3.

Both birds in the photos began biting and twisting their bills on small branches and raised areas of bark on May 3, 2017, three days after the photos on page 4 and 5 were taken of their bills on May 1. The following photos were taken of the light RECR fledgling reaching for and biting on the bark or short broken off branches on the main branch used for a perch. After taking hold of the protrusion on the main branch, this bird would twist to make the upper bill go to the left and the lower bill to the right. Its sibling twisted its bills the opposite way.


The light RECR just before hopping to its left to twist on a piece of bark that stuck up on the branch. Then it reached down and twisted. I shot the photo slightly too soon, just before it took hold of the bark. Since I was using flash, it took quite a while for the camera to process a photo and be ready to take the next photo.

When the bird reached down and grasped the bark shown in the photo on page 7, I took the photo just before the bird twisted and let go. The birds do this reaching and twisting very quickly. I didn't realize that it would be so difficult to get a photo. Unfortunately, it was too dark in the box for the camera to take video. I took a lot of photos like the two above over the next three days that showed the light RECR just prior to or just after twisting on the bark or short branch before I finally got one with the branch actually in the bill. After many more tries like the ones above and lots of blurry photos, I finally succeeded in getting the photo on page 7 of the light RECR twisting on one of the small broken branches. These photos and the photo on page 7 were taken on May 8, 2017. The dark RECR fledgling wouldn't pry when I was watching it. I guess it expected to be fed. However, I could peek into the box and watch it twist its bills on the bark or short branch stubs when it couldn't see me. After I succeeded getting the photo of the light RECR holding the short branch in its bills, I had to leave for the rest of the afternoon. The next day, I was busy for much of the day so didn't get any photos that day, but I saw them both twisting their bills when I peeked in at them before checking on their food and water. After May 10, I didn't see either of them twisting their bills. As both bird's bills were permanently crossed, they didn't need to twist them any longer. After photographing both birds' bills from both sides and top and bottom on May 11 (shown on page 9 and 10), I put them in a large flight room. In the next week, they built up their flight muscles and their bill tips grew somewhat longer. When they could fly well and were experienced at removing the seeds from pine cones on pine branches placed in their room, they were released where they could join the mixed flock of finches that came to our bird feeders. We have a large number of old Ponderosa Pine trees with many cones on them on our land.

From the inferred day of hatching on April 3 or 4, to the end of the bill crossing process on May 10, would make the birds 38 or 39 days or approximately 5½ weeks old when the bills were permanently crossed and the birds could extract seeds from pine cones. This time period was apparently not previously known, since the studies, Wikipedia and other sources of information didn't have the timing even close to correct. However, the age of the birds when the bills are permanently crossed may vary by a day or two in the wild, because of inclement weather, food availability or other factors that might affect nourishment and growth of the hatchling birds, thus making the period somewhat longer, up to 6 weeks from hatching to permanently crossed bills.

As previously stated, as soon as the bill tips go into the fast growth mode, a young crossbill begins to bite on something, like a knot or a small branch, twisting its head sideways to cause the tip of the upper bill to go to one side and the tip of the lower bill to the other side. Whichever way the bird twists the lower bill determines whether it will go to the left or to the right of the upper bill, if your focus is on the lower bill, as some ornithologist's focus seems to be. Or whether the upper bill will go to the left or to the right of the lower bill, if your focus is on the upper bill, as it is for most regular bird watchers. I assumed that bird watchers referring to righties and lefties were talking about the direction of the upper bill.

After getting many photos of the light RECR reaching for a protuberance as in the photo above or just after it let go, I finally succeeded in getting the photo below of the bird actually biting on one of the branches to twist its bills. These photos were taken on May 8.

This is the photo of the light RECR fledgling twisting its bills on a branch.

The dark RECR fledgling twisted its lower bill to the left and the upper bill to the right as the tips grew. These photos were taken on May 8, 2017, the same day as I finally succeeded in taking my best photo of the light fledgling actually biting on the branch shown in the photo on page 7. On this dark RECR the bills as can be seen, are beginning to remain crossed.

The light RECR fledgling twisted its lower bill to the right and the upper bill to the left as the tips grew as shown by these photos, also taken on May 8, 2017. This bird's bills were not yet crossed quite as much as those of the dark RECR.

Once the bird begins to twist, it always twists the bills the same way each time, hundreds of times per day. The bills were permanently crossed in 5 to 6 days, when the bill tips were long enough to keep the bills permanently in the crossed position. I had no way to determine whether the direction of twist is genetically programmed or if it is individual preference, but researchers have shown that the upper bill on approximately half of Red Crossbills are crossed to the right and approximately half to the left.

Since these two birds were siblings, they likely had the same genetic makeup, although females of some species mate with more than one male. I could find no research on this issue in crossbills. One of my two birds twisted its lower bill to the left and one twisted its lower bill to the right. Thus what determines "why" a specific bird twists so the lower bill goes to the left and the upper to the right, or twists the opposite way was not determined, but this may be because of what was suggested in a study by Knox (Knox, 1972), which is referenced in a study by Craig Benkman. Dr. Benkman told me he had not observed young crossbills during the fast growth period of the bills so had not observed the birds twisting their


The photos on this page are of the bills of the dark RECR fledgling on May 11, 2017. As can be seen, on that day, it had much longer upper and lower bill tips that were in their permanently crossed position. This bird twisted so the lower bill went to the left and the upper bill went to the right.


The top and bottom views of the dark RECR on May 11, clearly show the long bill tips in their permanently crossed position. In the bottom view on the right, it can be seen that the lower bill tip has been bent slightly to the left and the upper bill has even more obviously been bent to the right.


This page shows the same four views of the bills of the light RECR on May 11, 2017 after its bills were completely and permanently crossed.


In top and bottom views of the bills, the upper bill had been twisted to the left and the lower bill had been twisted to the right. The bills are in their permanently crossed position. The bend in the bills is not as obvious on this bird as on its sibling's bills shown in the photos on page 9, especially the lower bill.

bills to make them cross. He said he believed what previous researchers had said in their studies concerning this aspect, but he found my photos intriguing. He suggested that I would have to do a large study with many young crossbills, saying a group of birds that were free to make their bills cross and a group of controls to show what would happen if the young birds were prevented from making their bills cross would be needed. I had already sent him the photos of the post-fledgling crossbill with a broken leg, discussed and shown in photos on page 12, 13 and 14. I asked Dr. Benkman how I would be able to "control" a group of healthy, uninjured crossbill fledglings, but he had no answer. I told him that the controls would all have to be euthanized because they wouldn't be able to eat or drink with the bills permanently held apart by the long upturned lower bill growing into the bottom of the upper bill so the mouth is permanently held open. I said a rehabber would never do that to a healthy bird and neither would an ethical researcher. Having served on an Animal Control and Use Committee for six years, I am certain that such a study would not, or at least should not be approved.

The following paragraph is what Dr. Benkman said in his study about the direction of crossing (Benkmam, 1996). http://www.uwyo.edu/benkman/pdfs%20of%20papers/benkman_1996.pdf

"Whether the direction of crossing is environmentally (James et al., 1987; Groth, 1992) or genetically based (Benkman, 1988a; Groth, 1992) has been the focus of much speculation but few studies. However earlier unpublished observations of nestling Red Crossbills (Loxia curvirostra) (H.B Tordoff, per. comm.) show that there is likely to be little environmental influence on the mandible crossing direction. Tordoff had a captive breeding colony of Red Crossbills and he found that nestling crossbills consistently abducted their lower mandible to the side to which it later crossed. The asymmetric jaw apparatus and possibly even the asymmetric jaw musculature (Knox, 1972), apparently begins to develop early in the nestling stage and possibly even while in the egg. Thus, even though the mandibles begin crossing several weeks after fledging (Newton, 1972) the direction the lower mandible crosses is determined much earlier in development. Although this does not eliminate environmental effects on the mandible crossing direction, it makes it extremely difficult to envision phenotypic variation as an adaptive response to environmental variation since parents feed nestlings regurgitated seed kernels."

If as Knox observed, the direction the lower mandible crosses is determined early in development, his observed asymmetry of the jaw could be the stimulus or genetic trigger for the direction the birds twist their bills. However, the statement "the mandibles begin crossing several weeks after fledging" Benkman attributed to Newton (Newton, 1972) is not consistent with what I documented on the young crossbills. For example, it was almost 2 weeks between the photo on page 1 taken on April 13 of the hatchling dark RECR and the next photos on page 3 of the same bird as a fledgling on April 26. On April 26, both birds could fly and eat sunflower seeds and other bird food by themselves, thus I would assume they would have fledged around that time. Then a little over a week after April 26, on May 6, the two siblings began twisting their bills on protuberances on the branches in their flight box. That was right at the beginning of the fast bill tip growth. They had stopped all twisting by May 11, when the fast growth period had ended and the bills were permanently crossed.

I received the two birds whose photos are in this document for care when they were older hatchlings, with their feathers still growing. I assumed the birds were between 9 and 11 days old when I received them on April 13. So they would have been around 36 to 38 days or approximately 5½ weeks old when the bills were permanently crossed and the birds could remove the seeds from cones. If the birds fledged at approximately 2 weeks old, give or take a day or two, it took slightly over three more weeks until the bills were permanently crossed. That could be called "several weeks after fledging," but why not say approximately 3½ weeks rather than "several weeks," which could be any where from 3 to 6 or 7 weeks. Clearly, no crossbill researcher had actually continuously observed fledgling crossbills from before the bills were crossed until immediately after, or they would have known how long after hatching it took for the bills to be permanently crossed. I could not find the precise time period mentioned in any of the many studies on crossbills I have read. If anyone else has, please send the reference to me at bjhoy@localnet.com.

In their study, Edelaar et al. (2005) stated the following in their abstract. "Unusual among birds, the bill tips in crossbills (Loxia spp.) overlap in the vertical plane, with the tip of the lower mandible to either the left or right of the tip of the upper mandible when viewed from above. Patterns observed in wild populations and experimental foraging data suggest that a 1:1 ratio of left- to right-crossing individuals is maintained by frequency-dependent natural selection in some populations, and that genetic drift causes deviation from a 1:1 ratio in other populations. Both processes require a genetic basis for this remarkable polymorphism, yet few data are available that address whether, and how, mandible crossing direction is heritable. To test for a genetic basis of this trait (single or quantitative, autosomal or sex-linked), we analyzed resemblance in mandible crossing direction between related captive-bred individuals of several crossbill taxa with standard statistical techniques as well as modern animal model methodology. Surprisingly, we did not find statistically significant support for a genetic basis of mandible crossing direction. Comparisons of the ratio of left- to right-crossing males and females in wild populations also did not support a sex-linked quantitative genetic basis. We conclude that mandible crossing direction may have uncharacteristically low heritability, but we cannot rule out that it is nongenetically determined." (Pim Edelaar, Erik Postma, Peter Knops, and Ron Phillips. "No Support for a Genetic Basis of Mandible Crossing Direction in Crossbills (Loxia Spp.) *The Auk* 122, no. 4 (2005): 1123-129.) https://www.jstor.org/stable/4090517

The findings in this study by Edelaar et al. does not preclude the birds themselves making their bills cross by twisting their bills as other rehabbers and I observed. Additionally, Benkman stated in one of his studies http://www.uwyo.edu/benkman/pdfs%20of%20papers/benkman_1996.pdf "---the asymmetry and thus the direction the lower mandible crosses is before the fast growth of the bill tips, this does not eliminate environmental effects on the mandible crossing direction." Phenotypic variation occurs when the expression of the genes is changed in response to the environment. It would seem that the birds twisting their bills to make them cross would be considered an environmental effect. Any asymmetry of the jaw, if there is such, likely occurs during development in the egg. Thus the asymmetry might be the genetic stimulus that dictates the direction the bills are twisted by the birds themselves? However, nothing I observed on the birds, indicated asymmetry of the jaw exists prior to the birds doing the twisting of the bill tips.

What was definitely observed and documented by rehabbers is that the birds twisted their bills using bark or short branches to make the upper bill and the lower bill go the direction the bird begins to twist them when the fast growth period begins. I should note here that several rehabbers I know are biologists who earn their living by working as biologists and I am a biologist who has co-authored several published peer reviewed papers on plants and animals, but was never paid for work as a biologist. Obviously, the fast growth of the bill tips on the fledglings when it is time for them to begin procuring their own food, as well as the downward curve of the upper bill as it grows and the upward curve of the lower bill as it grows are triggered by the genes of the crossbills. However, the young birds in the photos shown herein definitely proves that the bird itself, twisting the bills on bark and branches, determine which direction the upper bill and lower bill crosses. Neither photos nor close observation showed whether the direction is choice or is genetically triggered. However, the drawings of jaw muscles from Wikipedia, shown below on page 16, drawn by William Yarrell for his 1843 paper on crossbills, may be a clue as to how the direction is genetically triggered.

THE CONTROL POST-FLEDLING RED CROSSBILL THAT WAS UNABLE TO TWIST ITS BILLS

Over 15 years ago, I was asked by Craig Benkman what would happen if a young crossbill was not able to twist its bills while the tips were in the fast growth mode. In spring of 2008, I received a fledging Red Crossbill with a broken leg who answered that question. It was brought to me right at the beginning of the period of fast bill tip growth. I splinted the leg and propped the bird upright with rags. In the middle of a nest of soft fabric and unable to stand, the bird was not able twist its bills at all while the bill tips grew. The question of what would happen was soon answered. The tip of the fast growing lower bill began pushing up against the underside of the front of the upper bill, which was also growing rapidly, but in a downward curve. The fast growing upturned lower bill forced the bird's mouth to remain open. That condition is clearly shown in the two photos of that fledgling Red Crossbill below on page 13.

I had to tape the bird's bills in a crossed position between feedings to make its bills grow permanently crossed, so the bird would be able to close its bills, drink, eat and remove seeds from pine cones. By the time the leg was healed and the bird was walking normally, about 9 days after I received it, the bird's bill tips were fully grown and crossed (see photo on page 14). Consequently it did not bite and twist on anything after it was able to use its legs. My taping the bill in a crossed position appeared to be a success. The bird was able to extract pine seeds from pinecones I provided. It put its crossed bills between the scale and the cone shaft in the normal way for crossbills, opened its bill to expose the seed, removed the seed with its tongue and ate it. Because it had obviously been flying around with its parents and siblings before being injured, it knew how to remove pine seeds from the cones and did so immediately after it could use its healed leg. After it had built up its flight muscles in a flight room, I released it in our yard near our bird feeders. It joined the other finches in the mixed flock of finches coming to our feeder. I saw it at the feeders a few times during the next week. Hopefully, it eventually found and joined a flock of Red Crossbills.

The two photos below show the injured crossbill's bills prior to taping them crossed, showing the tip of the lower bill growing upward directly into the bottom of the upper bill and forcing the bird's mouth to remain permanently open. As the lower bill tip grew longer, the bills were forced to remain further apart. The bird would not have been able to eat or drink if I had allowed this to continue. A rehabber's job is to get a bird ready for a normal life and eventual release, which is why I taped the bills in a crossed position. I had to remove and then replace the tape each time I fed the bird, about every 20 to 30 minutes except at night when the bird and I were sleeping.

This photo shows the straight-forward bills on the young crossbill with the broken leg before I taped the upper bill to the left of the lower bill.

This is a side view showing the straight bills before I taped the upper bill to the left of the lower bill. There was no indication at all which direction I should make the upper bill go, but as can be seen in the next photo, the taping worked.

This photo shows the same post-fledgling after the bill tips had finished their growth. I determined which way the lower bill crossed on this bird since I taped them in this position, the bird didn't decide and likely its genes weren't involved. However, there was a 50% chance I taped the upper bill in the direction the bird would have twisted it. In any case, its bill tips permanently remained in the crossed position in which I taped them and worked perfectly to remove seeds from pinecones.

DISCUSSION REGARDING OUR HYPOTHESIS THAT CROSSBILLS PHYSICALLY CAUSE THEIR BILLS TO CROSS AND SUGGESTIONS FOR FURTHER STUDIES

The null hypothesis as stated to me by researchers who studied crossbills is as follows:
"The bills on young crossbill species cross with the lower bill tip going to the left or to the right of the upper bill tip at some point during development because of genetics, with the birds themselves having no part in the process."

From observations by myself and other rehabbers and the photos in this document, this null hypothesis was not proven and in fact was shown to be mostly false. Also, I could find no observations, documentation, data, photos or other information in published crossbill studies that provides any evidence or verification for the null hypothesis.

Based on the evidence shown in the photos in this document, this is the correct hypothesis for how the bills of post-fledgling crossbills become crossed. **"The fast growing bill tips on crossbill species are curved to cause the lower bill to go to the left or to the right of the upper bill by the deliberate behavior of the post-fledgling crossbills themselves. Those behaviors consist of biting and twisting on protuberances like bark and small branch stubs, beginning at around 4½ weeks after hatching. The biting and twisting is done by the post-fledging birds hundreds of times per day, until the fast growth of the bill tips stops and the bills are successfully crossed at approximately 5½ weeks old. "**

As has been shown in the photos in this document, each bird begins to twist the lower bill in one direction and the upper bill in the other direction and continues to twist many times a day in the same way until the tips are permanently crossed when the bill tips finish their fast growth a approximately a week later. It is presently unknown whether the bird itself

decides the direction of twisting or if it is somehow genetically determined. Based on the photos of the two 2017 Red Crossbill fledglings, until the birds begin to pry their bills, there was no visible evidence in the shape of the bills or the behavior of the birds to indicate which direction the fast growing bills would eventually be twisted. This does not imply that the direction each bird twists is not genetically programmed as there was no evidence to show whether it was or not.

When I taped the bills crossed on the 2008 injured Red Crossbill fledgling, I made the decision to make the upper bill go to the left and the lower to the right, still the bird's bills were successfully crossed. What happened on that bird regarding the lower bill growing into the bottom of the upper bill and forcing the mouth to remain open until I taped the bills in a crossed position may support the hypothesis that genetics may not dictate which way the bills have to be crossed. However, since I had a 50-50 chance of making the bills cross the way the bird would have twisted its bills if it had been able to stand and twist, I don't think what happened with this bird proves anything about that particular genetic factor.

Hopefully, this document is sufficient evidence to prove that fledging crossbills do twist their bills to make their bill tips cross, thus disproving the null hypothesis. If the bills "genetically" grow into a crossed position, with the bird having no part, the bill tips should have done so on the crossbill fledgling with the broken leg. Obviously there is no monetary gain or any other reason for crossbill researchers and other ornithologists to insist their hypothesis, that the bills just suddenly cross is true. One has to wonder why there is so much resistance against giving the young birds credit for what they do themselves with regard to making their bill tips cross by their own actions.

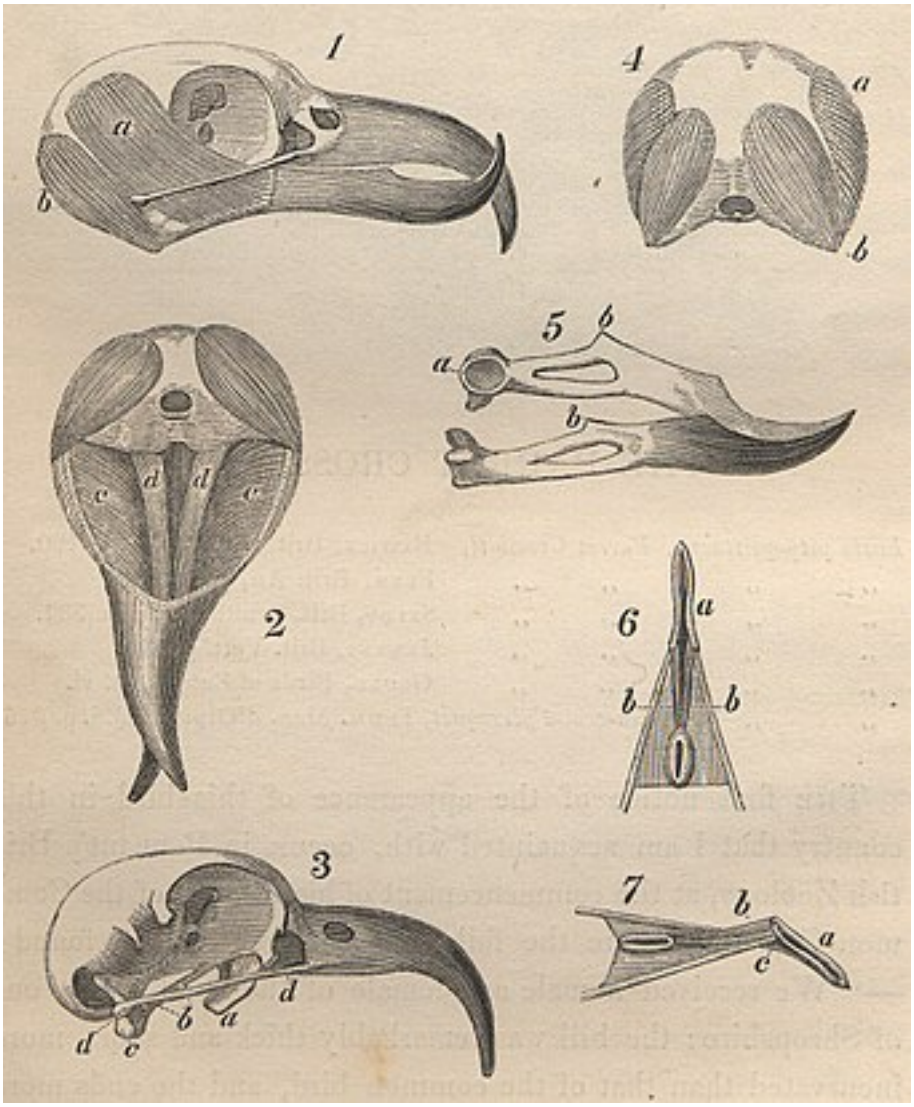
After reading what it says about crossbills in Wikipedia, it appears that some of the information on young crossbills posted there is also incorrect. Here are two such paragraphs about crossbill youngsters that contain misinformation.

"The mechanism by which the bill-crossing (which usually, but not always, occurs in a 1:1 frequency of left-crossing or right-crossing morphs) is developed, and what determines the direction has hitherto withstood all attempts to resolve it." As shown in this document, this statement is actually not correct concerning the mechanism, **since the mechanism is the bird itself making its own bills cross by twisting the bills during the fast growth period of the bill tips.** I reported this observed mechanism to crossbill researchers, including Dr. Craig Benkman over 10 years ago. It would seem that crossbill researchers who have captive crossbills in aviaries could have put up cameras by now, to record what the crossbill youngsters do when the researchers are not directly observing them. The researchers could then see that **the birds themselves determine the direction the bills cross by each bird twisting its fast growing bill tips to make the bills cross in the direction the bird itself twists them.**

The other Wikipedia paragraph is as follows, "It is very probable that there is a genetic basis underlying the phenomenon (young birds whose bills are still straight will give a cone-opening behavior if their bills are gently pressed, and **the crossing develops before the birds are fledged and feeding independently),** but at least in the red crossbill (the only species which has been somewhat thoroughly researched regarding this question) there is no straightforward mechanism of heritability."

This statement - **"the crossing develops before the birds are fledged and feeding independently"** is completely incorrect. The young crossbills other rehabbers and I raised **could fly and eat sunflower seeds and thickened baby bird food by themselves for over a week before the fast bill tip growth began**. Thus they had been doing these behaviors **for about a week and a half after fledging. This was well before the fast growth began in the bill tips, at which time the birds began twisting their bills to make them cross. They were a few days over a month old when the twisting began and between 5 and 6 weeks old when the bills were permanently crossed.** In the wild, the parents continue to feed pine seeds to the fledgling birds until their bills have successfully crossed. However that doesn't mean that the young birds do not eat plant seeds or possibly pine seeds they find that have fallen to the ground before they make their bills cross.

Regarding the direction the individual bird twists its bills, obviously something stimulates the individual crossbill post-fledgling to twist its lower bill either to the left or to the right and of course the upper bill the opposite way when the fast growth period begins. It is easy to understand how the rush of growth hormones that stimulate the bill tips to grow much faster for several days would likely also genetically stimulate the bird to twist its bills to make them cross. However, close observation did not indicate what stimulates the birds to twist their bills in the direction they do. Several studies have shown that about half of Red Crossbill youngsters are lefties and half are righties. So about half twist the lower bill to the right and upper bill to the left and about half twist the bills the opposite way, but no study says what might stimulate each individual bird to do what it does.



From Wikipedia https://en.wikipedia.org/wiki/Crossbill, this is a drawing from an 1843 paper by William Yarrell that shows the skull and jaw anatomy on an adult crossbill.

In the above drawing of the muscles of the jaws by William Yarrell, the muscles on the left side are shown to be somewhat larger than those on the right of the bird's head in drawing (Number 4). I have no idea if a drawing of a crossbill with the lower bill going to the left of the upper bill would have larger muscling shown on the right side of the bird's head. The tip of the upper bill is drawn curved to the left in a top view (Number 2) and the lower bill is drawn curved to the right. I observed such curves on the bills of birds I raised after the bills had crossed. Those curves in the bills are visible in my photos after the bills have crossed. What I can't understand because the explanations for what are in the drawings are not included on Wikipedia, are drawing (Number 6) and drawing (Number 7). Drawing (Number 7) is especially puzzling because of the severe bend making it, whatever it is, look broken. The anterior of the bills on crossbills after the bill tips are crossed are slightly bent to the side, but not broken.

I don't like birds to be deliberately killed even for science. However, it should be possible on dead birds that have accidentally been killed to x-ray the skull and jaw bones and then closely examine the muscles on the sides of the head of hatchling crossbills to determine if the muscling is different for each side as this drawing suggests. However, my astute husband Bob pointed out that Yarrell's drawing depicts the jaw muscles on an adult bird. Thus, the muscles on the side of the jaw that had to work the hardest, the left side on the specimen drawn by Yarrell, would most likely be larger than the muscles on the right. Such a difference would likely not be evident for the muscles of a hatchling or a fledgling prior to making its bills cross. It seems that in the 178 years after Yarrell published his drawing, someone would have thought of examining and comparing the muscles on dead hatchlings, fledglings and adults. Depending on what is found such examinations possibly might help explain how and if there is a "straightforward mechanism of heritability."

In this age of high technology, it should be simple to x-ray the jaws of dead nestling crossbills to determine if they actually have the asymmetric jaw apparatus and the asymmetric jaw musculature that Knox reported (Knox, 1972) and that Yarrell's drawing suggests on an adult. It should be easy to prove with x-rays and/or dissection of birds of various ages whether this asymmetry actually develops early in the egg, in the nestling stage, or if it only occurs on adults after the birds have successfully caused their bill tips to cross. Best of all, this type of research would not be inhumane if the heads of accident-killed nestlings, fledglings, post-fledglings and adults were used.

Finally and most importantly, in this age of cameras everywhere, if crossbill researchers still have crossbills in aviaries and want to observe how the young crossbills make their own bills cross, it should not be difficult to put cameras where fledglings can be constantly viewed and videoed. This would allow researchers to actually see how the young crossbills bite and twist on various protuberances on the branches on which they are perched to cause the tips of the bills to cross and after several days, remain permanently crossed. Such videos would show the live post-fledgling crossbills' involvement in the crossing of their own bill tips and how many times a day they twist their bills until the bills are permanently crossed. Such photographic evidence would prove our hypothesis that **"post-fledgling crossbills physically make their bills cross by twisting them continuously in the daytime during the period of fast bill tip growth,"** and at the same time the videos **would provide a more precise age for the birds when they make their bills cross, than is currently in the scientific literature**. Both of these factors seem to lack agreement or any actual data or proof in the current published crossbill studies or on most websites on the Internet where many people obtain information on wildlife.