

# Reversible temperature-dependent color change in *Anax junius*

Dave McShaffrey, April 2003

*Anax junius*, the Green Darner, is a large, migratory dragonfly common in most parts of the United States. May (1976) discusses the phenomenon in general, and Dunkle (2000) describes the actual color change exhibited in *Anax junius*. Corbet (1999), using material from a number of sources, gives the physiological basis for the color change as a temperature-induced movement of vesicles in the chromatophores of hypodermal cells which occurs at lowered temperatures. For those of you not technically minded, what this means is that cells under the cuticle (which is non-living) have the ability to scatter light in such a way that the light that travels to our eyes is perceived as blue. Under warm conditions, these cells are able to scatter the light, but as temperatures cool sacs within the cells move in such a way as to reduce the light-scattering ability, and the area turns a dark purplish color.

I became interested in this phenomenon in the summer of 2000 when, over the period of several days, I was finally able to photograph Green Darners perched. Normally during the day, males of this species patrol almost continually and it is rare to find one perched - let alone trusting enough to allow one to approach closely enough for photography. However, in the early morning hours of August, 2000, I discovered a large number of Green Darners perched in Dogbane (*Apocynum* sp.). The Dogbane was located in an old field setting in the Bradley Woods reservation of the Cleveland Metroparks in Cuyahoga County, Ohio. The nature of the field was such that tall trees bordering the field shaded much of it until about 9 am at that time of the year. Darners encountered in the field were usually encountered perched heads up with their backs to the sun, wings outspread perpendicular to the sun's rays. They were usually near the middle of the plant or even lower, that is they did not crawl to the tops of the plants. Individuals in areas where the sun had been striking for some time were quick to fly away, but individuals located in areas still in shade would remain motionless. I was able to photograph several of these individuals using a 400mm lens with extension tubes to allow for closer focusing. Distance from the camera to the subjects was not measured but was estimated to be about 8 feet.



Figure 1. Cold *Anax junius* on Dogbane, August, 2000.

When first encountered, the Darners were dark purple where they normally are blue (Figure 1), particularly along the tops of the abdomen. About 15 minutes after the sun had reached them, they reached a blue color (Figure 2). Some wing "shivering" was noticed during this time, but it was very sporadic. Wing shivering is used by many insects to warm the flight muscles in the thorax to a temperature where they can sustain flight.



Figure 2. Warm *Anax junius* on Dogbane, August, 2000. Both Figure 1 and Figure 2 were originally taken on slide film and subsequently scanned into digital format using a Nikon 2000 slide scanner. An effort was made during the digitizing process not to alter the colors.

During these encounters, I was more interested in photographing the dragonflies than I was in the color change, a phenomenon I didn't really know about until some weeks later when I had the slides back and was curious about the color shift.

On April 20th, 2003 at about 2:00 PM, I captured another adult male *Anax junius* on a small section of the Ohio-Erie canal just east of the Tuscarawas River north of Massillon, Ohio. This specimen was returned live to the laboratory at Marietta College in Marietta, Ohio where it was subsequently photographed. The specimen was placed in a refrigerator at 60 C overnight.

One series of photographs was taken the following morning (April 21) from approximately 7:15 AM to 12:00 PM. The initial photograph was taken at 7:19 AM. The specimen was placed on a light table illuminated by fluorescent lights. Digital photographs were taken using a Canon D-60 digital camera with a 100 mm macro lens and a ringflash (MR14-EX). While a variety of exposure techniques and poses were used, the images presented here were all taken at f16 with an exposure time of

1/60 second. The flash was set on automatic. The camera recorded images in the JPEG format at a resolution of 3072 x 2048 pixels; the compression setting was fine (i.e. minimal compression).

Between photographs the specimen was warmed by placing it on top of a computer monitor; a digital thermometer placed in the same location recorded a temperature of 32o C. The specimen was photographed in this warming mode at 8:29, 8:37 and 8:47 AM, then returned to the refrigerator. It was photographed in the cooling mode at 9:12, 9:41, and 10:59 AM for the images shown here.

Post-processing of the images was minimal, the brightness of the original images was increased 50% using Adobe PhotoShop 5.5, and a unsharp mask filter of 164% was applied to all of the images. In addition, they were cropped to size, and the image size was manipulated to fit them on this web page.

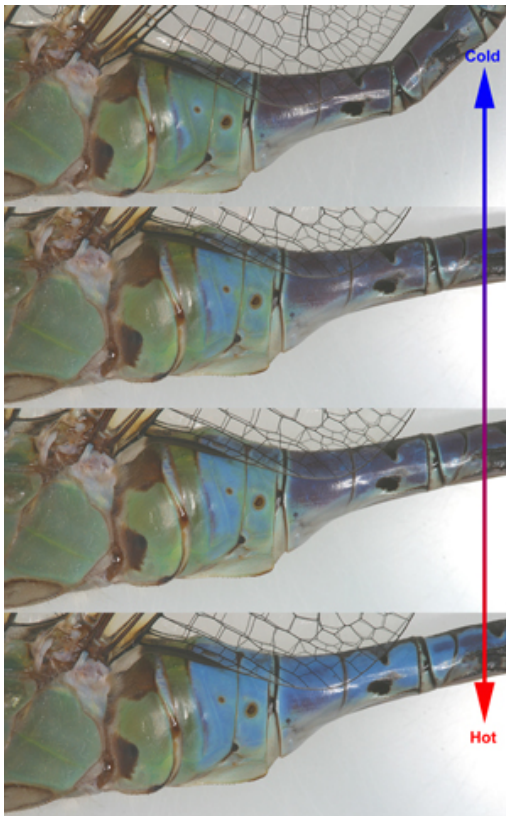


Figure 3. Color change in *Anax junius* abdomen as specimen is warmed.

[Click on image for larger version.](#)

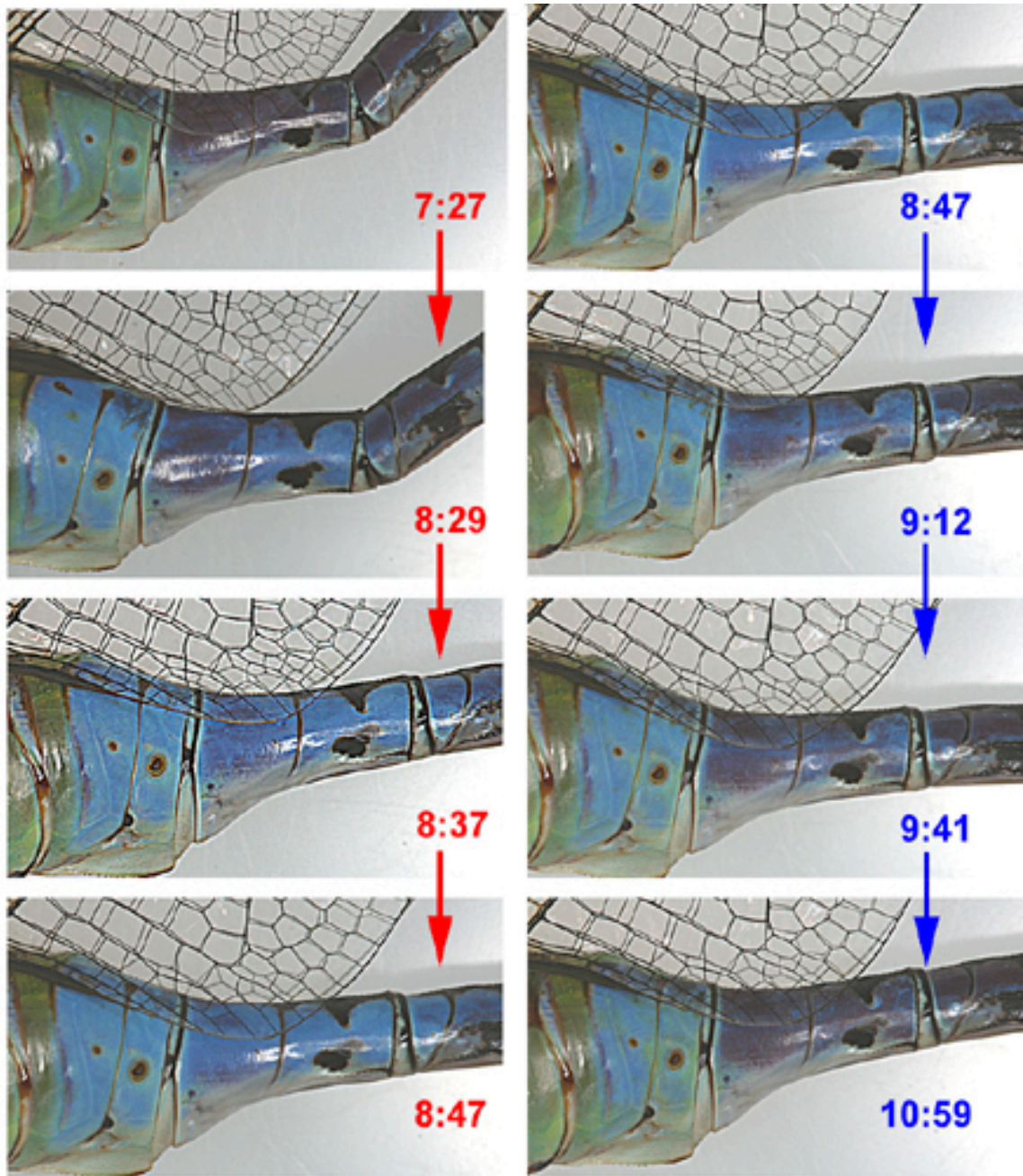


Figure 4. Color change in *Anax junius* abdomen as specimen is warmed and subsequently cooled. Numbers represent the time the photo was taken (all AM); red indicates the insect was warmed between photos, blue indicates the specimen was cooled.

[Click on image for larger version.](#)

While I took photos from several angles, I found the lateral views of the proximal abdominal segments to be the best for visualizing this phenomenon (I plan to repeat

this experiment after constructing a jig to hold the dragonfly with the wings outspread to make dorsal shots more practical).

Examining the images, one can see that it is not simply a matter of dark purple areas on the abdomen becoming bright blue as temperature increases; in fact green areas on the lateral aspect of the abdomen also change to blue. Also, note that the maximum blue color was reached in about 1 hour and 20 minutes, while cooling for over 2 hours did not cause all of the blue areas to lose their color as was the case when the specimen had been in the refrigerator overnight. Subsequent to the last photo in these series being taken on April 21 at 10:59 AM, the specimen was warmed again and was able to fly, albeit weakly. The image below (Figure 5) is an animation of the warming and cooling process and was compiled from the 8 pictures in Figure 4.

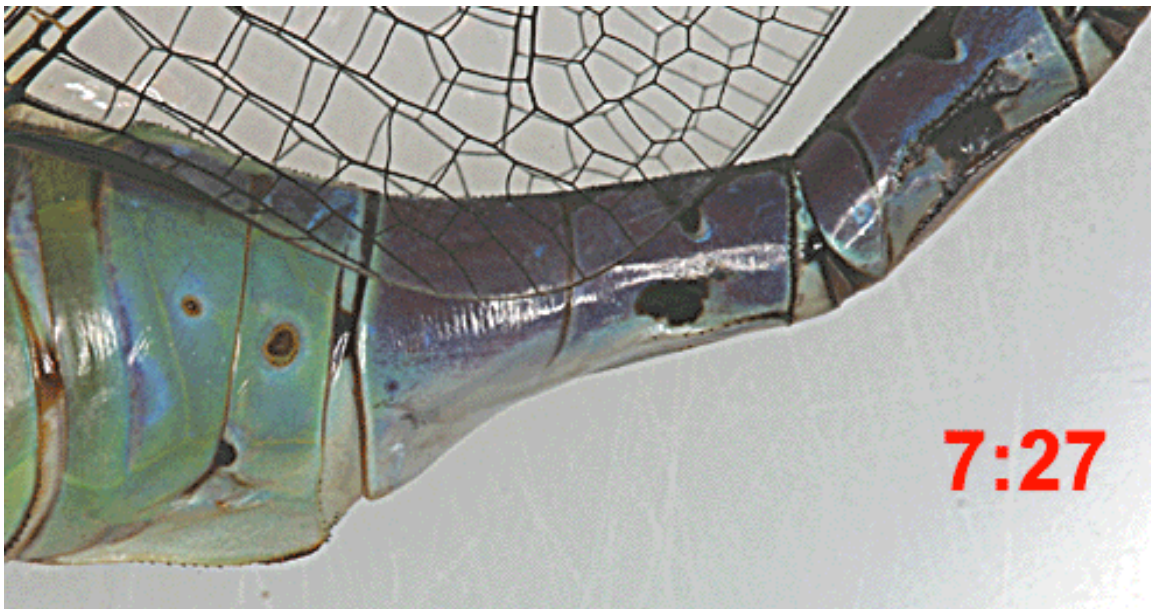


Figure 5. Animated GIF of the color changes upon heating and cooling *Anax junius*. This file is rather large; if your computer has not loaded it yet, why not read the article while you are waiting? Once again, the numerals indicate the AM time the image was taken; red numerals indicate warming the specimen, blue numerals indicate the specimen was being cooled.

I hesitate to draw any conclusions upon the observations of a single specimen, but several questions and avenues for future research are readily apparent:

First, is there any adaptational significance to the dark purple color that much of the abdomen assumes under cool conditions? Certainly the bright blue of the warm adult male has evolved as a species and gender recognition signal, but what about the purple color? Does it have an adaptive purpose? Note that the color of the stems of the Dogbane (Figure 1) are reddish in color. Could it be that the color of

the abdomen early in the morning when the dragonfly is too cold to fly adds a protective camouflage? If so, do the darners choose the plant for this reason, or is this all mere coincidence in that the Dogbane just happens to be in the right place in the field (where the sun strikes first in the morning) and the dragonflies choose the plants because of this position rather than the coloration of the stems? Also, what happens in the case of females, which never get the blue coloration - do their abdomens turn purple as well, and do they roost in the Dogbane?

Since *Anax junius* are large, rather common, and usually available at the beginning and end of the school year in the United States, I would further suggest that this might make an interesting subject for a high school or college lab. Rather than using a digital camera, the specimen could be scanned on a computer scanner. Various sources of heat could be used including natural sunlight, incandescent lamps, heat lamps, even heat from computer monitors, and the amount of blue showing could be quantified using programs such as Adobe Photoshop in conjunction with imaging software available as freeware from the Scion Corporation (<http://www.scioncorp.com/>). With care, the specimens could even be released after the lab.

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#### Literature Cited

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Corbet, P.S. 1999. *Dragonflies: behavior and ecology of Odonata*. Cornell University Press, Ithaca, NY. 829 pp.