ON INSECT COLOURS.[1]

II.

NOW it is necessary to explain the "reversion effects" of red, so frequently alluded to. I am tempted to give a detailed account of the experiments made in this connection, but the length to which this article has already run warns me that I must be very brief indeed: and I will therefore content myself with giving simply the broad results.[2] All reds and pinks (always omitting the last four in the table), are turned orange or yellow instantly by acids. When nitric acid is used, this effect is *permanent;* and whether the yellowed wing be dried, or washed, the yellow is immovable. I have kept such wings for five or six months, and they were as yellow as possible at the end of that time. In the case of all other acids,[3] the *yellow is permanent only so long as the wing is actually acid:* directly the acid is removed, the original red returns; and thus a wing may be alternately yellowed and "reverted" time after time. This reversion to the original red may be produced either by long exposure to the air, allowing the last traces of acid to drain off; or instantly by neutralizing the residual acid with a drop of ammonia, *or by copious washing.* It must therefore be understood that, with the exception of those cases in which nitric acid has been used, the permanency of the artificial yellow is *entirely dependent upon the presence of acid:* remove the acid, and the yellow vanishes. Accordingly, I have suggested the following explanation. Let us denote the molecule of red pigment by X; when any acid, except nitric, is added, I assume that this forms with X a so-called molecular compound: for instance, on treating with hydrochloric acid, we should get the hydrochloride of X, viz. $X.(H.Cl)_n$; and it is evident that these hydrochlorides, hydrosulphates, &c., of X are yellow, although the original X is red. To all these facts, of course, there are ample analogies known to chemistry. Next, for the resuscitation of red. We must suppose—what is certainly to all appearance very clear—that these molecular compounds are very unstable; an easily understandable fact; and that consequently the addition of even excess of water is sufficient to decompose them, removing the acid molecule, and thus restoring the pigment X to its original condition. Far more rapidly does this resuscitation occur if a drop of ammonia be used, this at once combining with the acid and liberating the X molecule. In the case of resuscitation produced by slow air drying, the action apparently would be in some cases due to gradual evaporation, or to some process of oxidation—anyhow producing dissociation of the molecular salt of X. Finally, in the case of nitric acid, it is clear that this acid does not form a molecular compound, but, as we might expect, exercises a permanently destructive action on the original pigment. Admitting that red has been developed from yellow, it is not surprising that it may be easily reconverted permanently into yellow by such a reagent as nitric acid. Before quitting this topic, I may point out that the cyanide reaction of the yellows is very suggestive indeed as to the kind of process by which the red pigment is developed from yellow.

Now, as to the last four species noted in the table. In these, I believe, the red is not developed from yellow at all, but from its close analogue, chestnut. Up till very recently, I supposed *V. atalanta* to be the only representative of such development, and was rather surprised that yellow should so commonly develop into red, and chestnut so rarely. But recently I have found that *Anartia amalthea* is exactly identical in behaviour with *V. atalanta*, whilst *Heliconius amaryllis* seems half-way between these species and the normal reds, but nearer to the former. The evidence on which this conclusion as to the nature of the red in *V. atalanta* was founded is as follows. The red of *atalanta* does *not* change to yellow, but to the brown or *chestnut normally present* in *V. cardui*, or to a more colourless tint. The change is not similar to that of red to yellow, but is a solution effect: consequently *no reversion effect* can be obtained; and this alone is almost decisive. It seems to me especially interesting that this experimental conclusion as to the nature of *atalanta* red is entirely corroborated by totally independent evidence from the entomological side, since the connection of *V. atalanta* and *cardui* is exceedingly close, and there are transition forms between them.[1]

And now we come to the last colour—chestnut—for which a very brief account will suffice, in addition to the details already given in the table, and the incidental remarks made during the discussion of yellow. It must be understood, then, that the constitution of chestnut appears to be very close indeed to that of yellow: like as in yellow, we can distinguish several stages of solubility, although deepening colour still less implies decreasing solubility even than it does in yellow—a conclusion which will be borne out by an examination of the table. Like yellow, chestnut may develop into red, as has already been explained; and the brilliant copper colour of *Lycæna phlœas* and *virgaurea* appears to occupy, both in its extreme solubility and its relation to the main line of development of the chestnut pigment, a position exactly analogous to that occupied by the orange of *E. cardamines* among the yellows. The only further remark that I have to make with reference to this colour concerns *V. io* and *V. antiopa*, which I have specially marked as notable examples. In these species the rich chocolate colour is very soluble, but leaves a *black* wing instead of a white. If chestnut had been developed from a white pigment, this would have been a grave difficulty; but it perfectly accords with the view that the pigment has been developed, not from any such white pigment, but in a previously unpigmented, usually white, wing; in these species it has been developed in a previously black wing. I have always considered the behaviour of these two species to considerably support my views of the nature of the chestnut pigment, and indirectly of the yellow.[2]

The main heads of the preceding pages may be very briefly summarized as follows. Blacks and whites are not pigment but absorption and reflection colours respectively. The great majority of blues are also physical colours—chiefly, if not entirely, interference colours; and it is doubtful if there be any pigment blues at all. Some greens are also physical colours, very similar to the blues; the character of another group is somewhat ambiguous, although probably these, too, are physical. A third group, is pigmental, and probably derived from yellow. All reds are pigmental, being developed chiefly from yellow, but in a few cases from chestnut; the former are characterized by the reversion effect. The great majority of yellows are pigmental, of various degrees of solubility or insolubility; but a few cannot at present be decisively pronounced either physical or pigmental, and the same remark applies to the chestnuts.[3]

In concluding this summary of my work, I must point out that it is not put forward as in any sense of the word final, even so far as it goes, but merely as a basis of systematic inquiry, in various directions. Up to the present, almost nothing at all has been known about the behaviour or character of these colours; now I will dare

[1] Continued from p. 517.

[2] A full account of these experiments will be found in the *Entomologist*, xxiii. pp. 39-40 and 53-59.

[3] I have used hydrochloric, sulphuric, acetic, phosphoric, hydrofluosilicic, and oxalic acids, in these experiments.

[1] There is similar evidence in the case of *Anartia amalthea*. Two specimens of this were sent me for experiment. One was marked with a chestnut band, and one with a scarlet. This scarlet was at once changed into the chesnut normally present in the other.

[2] I am disappointed at having as yet come across no yellow species analogous to *V. io*. But in this connection I may call attention to the behaviour of the *green* species of *Cidaria*, which are changed to a brownish-grey. It is possible that these greens may be descended from yellow developed on an originally dark wing.

[3] Cp. the instances of *Vanessa io* and *antiopa*.

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to hope that at least a basis of operations has been found. May I also venture to ask that any other investigators who may not have already been working on this subject will do me the favour of allowing me for a time to continue my researches alone—so far, that is, as concerns the Lepidoptera, both *imagines* and larvæ—for I am planning various lines of research suggested by my previous work. As to the various other orders of insects, I shall be delighted if other workers who may have opportunities, that I have not, of obtaining abundant material, will take up the work, and determine how far my conclusions will hold for these other orders also.

Tables of Results.[1]

Initial of group.	Name of species.	Natural colour.	Effect of reagents.
R.	*Apatura iris*	Rich purple velvet glow	Chiefly unaltered; gloss destroyed by KHO.
,,	*Trepsichrois linnæi*		The glow much dulled.
,,	*Hypolimnas bolina*		The glow much dulled or unaltered.
,,	*Hypolimnas salamis*	Violet	Dull steel blue.
,,	*Papilio*—six species	Bright and pale blues.	Bronze; leaf brown; or steel blue; &c.
,,	*Morpho menelaus*	Brilliant blue	Less brilliant.
,,	*Papilio machaon*	Dullish blue	Greyish.
,,	*Limenitis sibylla*	Do.	Do.
S.	*Smerinthus ocellatus*	Do.	Greyish or unaltered.
N.	*Catocala fraxini*	Dull blue	No marked alteration.
R.	*Vanessa*—four species	Blue	Paler or unaltered; destroyed in *V. antiopa*.
,,	*Lycæna*—five species	Various blues	Usually slate colour; occasionally *greenish*.
R.	*Parthenos gambrisius* (upper surface)	Metallic green	Purplish bronze or blackish.
,,	*Hesperia* sp.	Dark metallic green	Do.
B.	*Urania fulgens*	Do.	Do.
R.	*Papilio polyetor*	Bronze yellow green	Brownish or blackish.
,,	*Parthenos gambrisius* (below)	Sage green	Dun brown.
,,	*Limenitis procris*	Do.	Dun grey.
S.	*Ino statices*, &c.	Glittering green	Bronze brown.
R.	*Argynnis paphia*, &c.	Deep foliage-green	Do.
,,	*Thecla rubi*	Almost arsenic green	Brown, *like upper surface*.
,,	*Papilio*—four species	Leaf green	Whitish; white; or yellow.
,,	*Eromia argia*	Very pale greenish	Paler or whitish.
N.	*Halias prasinana*	Green	Whitish; *ochre yellow* in one case.
,,	*M. orion*; and *D. aprilina*	Do.	White.
G.	*Larentia*, &c.—several species	Do.	White; occasionally yellowish white.
,,	*Cidaria miata*, &c.	Do.	Brownish grey.
T.	*Tortrix viridana*	Do.	Whitish.
R.	*Euchloe cardamines*	Pseudo-green	Black.
S.	*Smerinthus*, &c.—several species	Pink *	Yellow or yellowish.
B.	*Deiopeia bella*	Do. *	Yellow.
,,	*Actias luna*	Do. *	Do.
,,	*Attacus cynthia*	Do.	Colourless or faded.
,,	*Hepialus humuli*	Do.	Faint orange.
G.	*Hyria auroraria*	Do.	Yellowish or whitish.
,,	*Aristelia rubricata*	Do.	Dunnish colour.
R.	*Parnassius apollo*	Red *	Orange.
,,	*Delias hierte* and *eucharis*	Red (*)	Yellow: *then white*.
,,	*Papilio*—various species	Crimson, scarlet, &c. *	Yellow, orange, &c.
S.	*Zygæna filipendulæ*	Red *	Orange.
B.	*Arctia caia*	Do. *	Do.
,,	*Euchelia jacobeæ*	Do. *	Do.
N.	*Catocala nupti*	Do. *	Do.
,,	*Xanthia silago*	Reddish	Yellow.
R.	*Papilio vertumnus* and *constolochia*	Pale red *	Pale ochrish or bread colour.
,,	*Heliconius amaryllis*	Scarlet	Brown: finally white.
,,	*Anartia amalthea*	Do.	Chestnut.
,,	*Vanessa atalanta*	Do.	A "*cardui*" brown.

Initial of group.	Name of species.	Natural colour.	Effect of reagents.
R.	*Papilio machaon*	Palish yellow	White.
,,	*Heliconius amaryllis*	Very pale yellow	Do.
,,	*Catopsilia catilla* ♀	Light sulphur	Do.
,,	*Vanessa antiopa*	Dull palish yellow	Whitish.
,,	*Charaxes athamas*	Light sulphur No †	White or towards whitish.
,,	*Terias nise* and *vabella*	Lemon yellow †	Pure white.
,,	*Delias eucharis* and *hierte*	Yellow	Do.
,,	*Hebomoia glaucippe*	Deep orange	Perfectly transparent.
,,	*Colias edusa*	Rich yellow †	Pure white.
,,	*Gonepteryx cleopatra*	Bright brimstone	Practically white.
B.	*Hazis* sp.	Deep yellow No †	Unaffected or nearly white.
R.	*Euchloe cardamines*	Rich orange	White.
,,	*Gonepteryx cleopatra*	Do.	Through brimstone to white.
,,	*Gonepteryx rhamni*	Bright brimstone †	Towards whitish.
,,	*Colias hyale*	Pale brimstone †	Lighter or fairly white.
,,	*Polyommatus alexis*	Orange	Scarcely affected or towards whitish.
B.	*Hepialus humuli*	Dullish yellow	Sickly yellowish; nearly transparent.
G.	*Rumia cratoegata*	Pale brimstone No †	Towards whitish.
,,	*Camptogramma bilineata*	Dull orange No †	Towards or whitish.
,,	*Hyria auroraria*	Dull yellow	Whitish or white.
,,	*Abraxas grossulariata*	Palish orange	Towards white or white.
,,	*Venilia maculata*	Yellow	Unaffected, or paler, or white.
,,	*Angerona prunaria*	Brownish orange No †	Dulled or unaffected.
R.	*Papilio asterias*	Orange yellow	Usually unaltered.
,,	*Ornithoptera darsius*	Crocus gold	Practically unaltered; but some probably dissolved.
N.	*Eudryas grata*	Yellow	Transparent or rather faded.
B.	*Tithonea haumoni*	Do. No †	Much paler, or towards whitish.

The following yellow or orange-yellow species are almost or entirely unaffected:—

(R.) *Papilio thoas*, *polyxenes*, and *philenor*; (B.) *Deiopeia bella*, *Callimorpha hera* (no †), *Arctia villica*, *Citherona regalia*; (N.) *Xanthia silago*, *Triphæna pronuba* (no †), *Heliaca tenebrata*.

Initial of group.	Name of species.	Natural colour.	Effect of reagents.
R.	*Vanessa io* and *antiopa*	Chocolate	Blackish. N.B.
,,	*V. urticæ*	Rich chestnutish	Whitish.
,,	*Argynnis paphia* and *selene*	Rich chestnut	Whitish; faded; or nothing.
,,	*Danais chrysippus* and *hegesippus*	Do.	Very faded; or whitish grey.
,,	*Athyma nefta*	Dull chestnut	White or transparent.
,,	*Cœnonympha pamphila*	Pale chestnut	Whitish or white.
,,	*Hesperia sylvanus*	Chestnut	Faded or white.
,,	*Lycæna phlœas* and *virgaurea*	Brilliant copper	Much faded or whitish.
,,	*Vanessa cardui*	Chestnut	Faded or whitish.
,,	*Epinephile tithonus* and *janira*	Do.	Faded more or less.
,,	*Satyrus megæra*	Yellow chestnut	Little faded only.
,,	*Atella phalanta*	Rich chestnut	Faded or very faded indeed.
,,		Rich chestnut	Very faded indeed.
,,	*Athyma penus*	Yellow chestnut	Dulled.
G.	*Selenia illustraria*	Deep chestnut and chocolate	Scarcely affected.

The following species are chiefly or wholly unaffected:—

(S.) *Philampelas athemon*, *Darapsa myron*; (R.) *Dione passifloræ*; (B.) *Orgyia antiqua*, *Bombyx quercus*; (N.) *Orthosia macilenta*, *Mamestra oleracea*; (G.) *Cidaria suffumata*, *Coremia ferrugata* and *minutata*.

[1] These tables afford only a very condensed summary of results; for fuller details *vide Entomologist*. The initials R., B., N., G., S., T. in first column signify respectively Rhopalocera, Bombyces, Noctuæ, Geometræ, Sphingidæ, and Tortrices. The asterisk (*) against various red species signifies "reversion effect," and the mark † against certain yellow species that the "cyanide effect" has been obtained; similarly, No † that no cyanide effect can be obtained with that species.

F. H. Perry Coste.

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