

# Poultry Mutations Sub-Menu 1

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URL: [http://home.ezweb.com.au/~kazballea/genetics/mutations1\\_print.html](http://home.ezweb.com.au/~kazballea/genetics/mutations1_print.html)

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This section became quite large, so I've divided the mutation section into three pages:

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- Page 1: Feather Colour/Pattern mutations
- Page2: Leg/Skin, Eye and Ear-Lobe Colour, plus Physical Mutations
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**Mutation descriptions, within categories:**

## Plumage Colour/Pattern genes

- Primary Pattern – e locus (E, E<sup>R</sup>, E<sup>R-</sup> Fayoumi, e<sup>Wh</sup>, e<sup>+</sup>, e<sup>b</sup>, e<sup>s</sup>, e<sup>bc</sup>, e<sup>y</sup>, e<sup>q</sup>)
- Secondary Pattern genes (Pg, Ml, Db, mo, B, B<sup>Sd</sup>, Er, Co)
- Eumelanin enhancers (extending black areas, Ml, Cha)
- Eumelanin restrictors (Columbian restrictors, restricting black areas, Co, Db)
- Eumelanin diluters (Bl, lav, I, I<sup>D</sup>, I<sup>S</sup>, choc, c)
- Pheomelanin intensifiers (red enhancers Mh, Dk1, Dk2)
- Pheomelanin diluters (gold diluters S, Di, Cb, ig,)

## Feather mutations

- Feather types (frizzle, silkie, soft feather, hard feather)
- Feather placement (foot feathers, stubs, vulture hocks, crest, ear tufts, muff/beard, naked neck, nakedness)
- Feather rate of growth (slow feathering, tardy)
- Tail & saddle (rumpless, long tail- non-moulting, 8 main tail feathers, wry tail, henny feather)

## Leg/Skin colour

- Id locus
- White/yellow W locus
- Sex-linked white/yellow
- Plumage colour influences (dominant white, mottled, sex-linked barring)

## Eye Colour & ear lobe colour

- Eye colour (Sex-linked brown, pearl)
- Ear lobe (turquoise, white, Spanish, red)

## Physical Mutations

- Comb types (single, pea, rose, buttercup, breda , duplex, rough, sprigs)
- Spurs (multiple spurs, hen spurs)
- Toes (5-toe, Brachydactyl, etc)
- Leg length (creeper gene, Cornish gene)

## Size Mutations

- Sex-linked Dwarfing, bantams genes, etc



## The E locus Chicken/Down Colour Pattern

Below are the E locus genes.

Genes: E, E<sup>R</sup>, E<sup>R-</sup> Fay, e<sup>Wh</sup>, e<sup>+</sup>, e<sup>b</sup>, e<sup>s</sup>, e<sup>bc</sup>, e<sup>y</sup>, e<sup>q</sup>

Gene names: Extended Black, Birchen, Fayoumi Birchen, Dominant Wheaten, wild type, Brown, Speckled, Buttercup, Recessive Wheaten, Queen Silvia

Phenotypes: Black, Brown Red, Brown Red, Wheaten, Black breasted Red (salmon breasted hens), Brown (brown breasted hens), Speckled, Buttercup, Clay Wheaten, Queen Silvia.

\* note: "E<sup>R-</sup> Fay" is not recognised nomenclature for the Fayoumi Birchen allele, only used here for short hand purposes. Smyth (1994) listed a Birchen allele as E<sup>RB</sup>, the RB standing for "**red-brown downed birchen**". Possibly this is the Birchen allele found in Fayoumi fowl.



Above are the typical *e* locus down patterns, without columbian-like restrictors (except maybe *e<sup>bc</sup>* chick-Db). Columbian (*Co*) will change the appearance of *e<sup>+</sup>* & *e<sup>b</sup>* down (usually adds eumelanin pigment, particularly on the back), but not *E*, *E<sup>R</sup>* & *e<sup>Wh</sup>* (although *e<sup>Wh</sup>* with *Co* are changed to a buff colour if sex-linked gold is present, but remain cream if sex-linked silver). Both *E* & *E<sup>R</sup>* down are indistinguishable, with variation from all black (eumelanin) to black with white as shown above.

The *E* locus is important to learn with poultry genetics. The common *E* locus alleles are:

- *E* (Extended Black) –black/cream day-old chicks, adults predominantly black, but may have some pheomelanin (silver or gold) areas in hackles.
- *E<sup>R</sup>* (Birchen)- black/cream day-old chicks, adults predominantly black, but may have more pheomelanin (silver or gold) areas in hackles, wing bows, etc.
- *e<sup>Wh</sup>* (Dominant Wheaten)- cream day-old chicks, adult male Black Breasted Red, adult hen wheaten.
- *e<sup>+</sup>* (Wild type) – dorsal stripes & eye stripe- day old chicks, adult male Black Breasted Red, adult hen salmon-breasted.
- *e<sup>b</sup>* (Brown) – brownish day-old chicks, adult male Black Breasted Red, adult hens brown breasted – stippling.

The *E* locus alleles produce the base primary colour/patterns to which varieties are build upon. The *e<sup>+</sup>* allele is the wild -type, and produces the typical Black Breasted Red male- salmon breasted female phenotypes (as found in the Red Jungle Fowl, etc). All male phenotypes, except *E* & *E<sup>R</sup>*, have the Black Breasted Red colour/pattern.

\* Images used in the following photos are from [Feathersite](#), and the [OEGBCA](#) website.



\* Wild type  $e^+$  adult plumage and chick down



\* Wheaten  $e^{Wh}$  adult plumage and chick down



\* Brown  $e^b$  adult plumage and chick down



\* Birchen  $E^R$  adult plumage and chick down

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It is a recent occurrence the DNA sequencing of two Birchen alleles, as once previously thought of as only one allele - ie  $E^R$  Birchen. The following is a direct quote from Dr Ron Okimoto on the Extended Black and two Birchen alleles (quote from [Polish Chickens](#) - A Discussion of E - extended black ):

Dr Ron Okimoto....." We have found three different alleles of the melanocortin 1 receptor locus (MC1-R) that produce black downed chicks on an otherwise wild-type background. Our data indicates that the MC1-R gene is the E locus. The most dominant allele at this locus is the E extended black allele. It differs

from wild-type  $e^+$  by two mutations that change the amino acid sequence of the gene (Met71Thr and Glu92Lys). The Leghorn birchin allele we call  $E^R$  only has the Glu92Lys mutation and lacks the Met71Thr. Our hypothesis is that you need both mutations to get the blackest bird and that if you have only the Glu92Lys you end up with the birchin black phenotype. There is a third  $E^R$  allele that is found in Fayoumi. The Fayoumi birchin allele has a totally different mutation (Leu133Gln).

The most dominant E allele has varied expression in down color. Some chicks are black with gray bellies, and other show varying amount of cream color on their undersides. This color seems to be due to other genes than the E locus because I get both types of chicks with the most dominant E allele."

The following is another direct quote from Dr Okimoto, first discussing the E and  $E^R$  alleles, then  $e^b$  &  $e^{Wh}$  (quote from The Classroom @ The Coop -[Different Kinds of Black](#)):

Dr Ron Okimoto....."At the molecular level these alleles seem to be related. Birchin was probably the first mutation. It has the same mutation that causes black fur in some mouse lines. The E allele probably came second in addition to the birchin mutation the E allele has a second mutation at the same position that causes black wool in sheep. So the E allele has a double whamy that produces more black than the birchin mutation by itself can. The  $e^b$  allele has a third mutation. This just means that there was a bird with the E allele and it mutated to the  $e^b$  allele. This third mutation seems to be unique among animals and appears to act to attenuate the E allele so that the birds aren't black, but brown.

The wild-type  $e^+$  allele has none of these mutations. The dominant wheaten allele has a unique mutation that separates it from  $e^+$ . I haven't found a recessive wheaten allele yet. All wheaten samples that I've tested look identical to dominant wheaten. This may mean that the guys that claimed that other modifiers determined the dominance of wheaten may be correct."

The following is direct quote from Dr Okimoto on the DNA sequencing of E locus allele from the Silician Buttercup breed, by Leif Anderson. This indicates that the Buttercup pattern may be produced with the  $e^b$  allele in combination with other modifying genes, and that the  $e^{bc}$  allele had not been sequenced.

Dr Ron Okimoto (quote from [The Classroom @ The Coop](#)) ..... "Leif Andersen has sequenced the buttercup allele ( $e^{bc}$ ) and it is the identical sequence to the  $e^b$  alleles that I've sequenced in Partridge Rocks and the Smyth Brown line. If there is a difference between the alleles it is in the regulation of the gene and not in the coding sequence. There may be linked genes that affect the expression of the E locus too."

Further research by Dr Okimoto (quote from [Classroom @ The Coop: Blue & E/ or ER/](#), posted May 02, 2006) .....

Some of us speculated that Andalusian blue used  $E^R$  instead of E because  $E^R$  would be more amenable to secondary pattern genes like Pg. I recently tested some Andalusian Blues from McMurray. I had a mixed batch of chicks so I could only tell the gray ones as blues the blacks could have been something else. There were three gray chicks that produced gray chick feathers. Two were homozygous  $E^R E^R$  and the

third was heterozygous  $E^{ER}$ . My guess is that E probably causes the dark birds and that the show quality birds are probably  $E^R$ .

I had ordered 5 birchin Cochin bantams, but I may have gotten black Cochins by mistake because all 5 feather footed black chicks were homozygous for E and not  $E^R$ . I couldn't tell if there had been a mix up because we couldn't raise the chicks longer than two weeks in the isolation facilities. I found two weird alleles in McMurray Buff Rocks. I was looking for recessive wheaten, and it may be in those stocks. One allele has the dominant wheaten mutation, but it is coupled with the Fayoumi birchin mutation. You can speculate and infer that it might produce more black melanin than dominant wheaten.

There is another allele that has the  $e^b$  attenuating His/Pro mutation that turns the extended black allele to a brown allele, but the attenuating mutation is in the  $E^R$  sequence. My guess is that this allele produces less black than the  $e^b$  allele, how much less is anyone's guess. Someone would have to cross these Buff birds out to Brown Leghorns and backcross them to Leghorns while tracking the E locus alleles and getting rid of the columbian restrictors.

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In summary, there have been 7 E locus alleles sequenced:

- $e^+$  (no mutations)
- $E^R$  – Leghorn (Glu92Lys) {one mutation}
- E (Glu92Lys and Met71Thr) {two mutations, sharing 1 with  $E^R$ }
- $e^b$  (Glu92Lys, Met71Thr and His/Pro) {three mutations, sharing 2 with E}
- $E^R$  – Fayoumi (Leu133Gln)
- $e^{Wh}$  (? -dominant wheaten mutation)

# plus the following 2 alleles found in McMurray Buff Rocks:

- 1st allele:  $E^R$  – Fayoumi/ $e^{Wh}$  mutations (Leu133Gln & dominant wheaten mutation)
- 2nd allele:  $e^b$  on  $E^R$  allele (His/Pro and  $E^R$  mutation\*)

\* note, I wasn't sure if Ron meant the  $E^R$ -Leghorn mutation or the Fayoumi mutation, for the last allele.



## Eumelanin enhancers (extending black areas, MI, Cha)

\* Images used in the following photos are from [Feathersite](#), and the [OEGBCA](#) website.



These eumelanin enhancing genes are responsible for extending the typical black areas of the wild type in to the pheomelanin areas. The Brassy Back variety is a good example:



\* Brassy Back variety ( $e^+$  wild type plus eumelanin enhancer)

They are also responsible for extending eumelanin in the Quail and Vorwerk varieties: both Buff Columbian based varieties:



\* Quail variety ( $e^+$  wild type, Co Columbian, plus eumelanin enhancer(s))



\* Vorwerk variety ( $e^b$  Brown, Co Columbian, plus eumelanin enhancer(s))

Obviously there are differing eumelanin enhancing genes/genotypes in the Quail and Vorwerk varieties, as both varieties can be produced with the base genes:  $e^b$  Brown, Co Columbian plus eumelanin enhancer(s).

Research by Campo & Oronzco indicated that the synthetic variety "Melanised Prat" (Quail phenotype) has the genotype of  $e^{Wh}$  Co Ml. Smyth segregated a possibly new dominant eumelaniser (ie not Ml, possibly Cha) from OEG Brassy Backs. Jeffrey segregated a recessive eumelaniser in OEG Brassy Backs & Quails.

Smyth produced a Lakenvelder phenotype from an  $e^b$  line, which segregated Co and Ml, plus additional eumelanin enhancers. Once the Columbian gene was removed, he segregated  $e^b$  solid black birds. Yet  $e^+$  Quail lines usually segregate Brassy Back phenotype when the Columbian gene is removed. It also needs to be determined why Vorwerk/Lakenvelder hens have no quail-like hen markings (ie no eumelanised & laced back/wings), eg, is there another eumelanin restrictor present

in Vorwerk hens, or is the difference due to the eumelanisers present?

Eumelanin enhancing genes are also found in E solid black based varieties. The MI gene is found in the secondary pattern varieties: Spangled & Doubled Laced and Single Laced.

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## Melanotic allele: MI (1971):

First described by Moore and Smyth (1971), after extracting it from a randombreeding recessive white population previously described by Jeffrey (1947). MI is incompletely dominant autosomal mutation that extends eumelanin into the normally red areas of pyle-zoned fowl, while having little effect on the chick down colour. Heterozygotes on wild-type (e+) or brown (eb) backgrounds are distinctly darker, particularly in the hackle and head; however, MI/ml+ has little effect on eWh/eWh females. Homozygotes approach self blackness, but the salmon pigment of the wildtype and wheaten females remain evident.

- • MI found in the Quail pattern (Campo and Oronzco, 1986)
- • The Melanotic gene by itself does not make a wild-type bird black.

MI (Melanotic) is sex influenced, autosomal incompletely dominant gene. This means that heterozygote hens with only one dose of the black enhancer (MI/ml+) show very little pheomelanin (gold or silver) on ER (birchen) base (ie acts like a dominant gene). Whereas, heterozygote roosters with only one dose of MI (MI/ml+) show more gold on the hackles, wing bows, etc, when ER (i.e, acts like an incompletely dominant gene). MI homozygous (MI/MI) & on its own doesn't cover all pheomelanin areas on e+ & ER male birds (although covers a lot), & doesn't cover salmon areas of e+ (eg, as in Brassy Backs) & eWh hens. Therefore, other eumelanin enhancers are needed to change the gold/silver areas to black (eumelanin). MI isn't expressed in day-old chick down, unless in combination with other mutations, eg eWh Co MI produces a heavily melanised chick down - research by Campo & Oronzco - Melanised Prat. Campo & Oronzco (1986) (and Campo, 1991) also noted that two doses of MI is needed to produce the dark chick down, & quail pattern in adult eWh Co birds.

Unsuccessful efforts to determine the genetic basis for certain “recessive black” lines (Punnett, 1957, Smyth, 1976) suggest the existence of more than one eumelanin intensifying mutation.

### References:

Crawford, R.D (ed.)(1990). *Poultry Breeding and Genetics*. Elsevier, Amsterdam.

Campo, J.L. and Orozco, F. (1986) *Genetic basis of the melanotic Prat phenotype*. British Poultry Science. 27:361-367.

Campo, J.L. (1991) *Use of the sex-linked barring (B) gene for chick sexing on an eumelanotic columbian background.* Poultry Science. 1991 Jul;70(7):1469-73.

Jeffrey, F.P. (1947). *Plumage color genes in White Plymouth Rocks and White Wyandottes.* Poultry Sci. 26:526-528.

Moore, J.W. and Smyth, J.R. (1971). *Melanotic, key to a phenotypic enigma of the fowl.* J.Hered. 62:214-219.

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## **Crawford (1986)- eumelanising gene 0.3 cM to Peacomb locus:**

Crawford segregated a eumelanising gene, closely linked with the P (pea comb) locus, only 0.3 map units apart (from "Poultry Breeding & Genetics, 1990).

## **Carefoot (1990)- Linkages of Ml with Peacomb locus:**

Carefoot, 1990 tested linkages again of Ml (Melanotic) with P (peacomb) loci, and found the loci to be 46 map units apart. It was suggested from this evidence that two eumelanising genes were in existence, ie Crawford's eumelanising gene was different to Ml - Melanotic. Therefore, Charcoal (cha) was suggested by Dr Crawford for the recessive gene linked with P by 0.3% (Carefoot, 1990).

## **Smyth (1994)- Charcoal:**

Smyth listed the Charcoal gene with the dominant symbol - Cha (Smyth, 1994).

## **Carefoot (2001)- Black Hackle of the Indian Game:**

Carefoot crossed Indian Games (pea-combed, black hackled) with Barnevelders (single-combed, partially black striped hackled), to determine the genetics of the neck hackle eumelanising gene found in Indian Games. He found the black hackled eumelanising gene to be closely linked with the P (pea comb) locus, and to be a dominant gene. Therefore, Carefoot suggested the eumelaniser appeared to be allelic to, if not a further manifestation of the Charcoal gene.

\*note: Carefoot mentioned in the above report that Smyth (pers. com.) investigated in Brassy Back OEGB a potentially new eumelanin extension that had a dominant charcoal effect on wild type.

References:

Carefoot, W.C. (1990) *Test for linkage between the eumelanin dilution blue (B1), the extended black (E) allele at the E-locus and the linked pea comb (P) and eumelanin extension (M1) genes in the domestic fowl.* British Poultry Science. 1990 Sep;31(3):465-72.

Carefoot, W.C. (2001) *Inheritance of the Black Hackle of the Indian Game bantam.* British Poultry Science. 2001 May;42(2):274-5.

Crawford, R.D. (1986) *Linkage between pea comb and melanotic plumage loci in chickens.* Poultry Science 65:1859-1862.

Crawford, R.D (ed.)(1990). *Poultry Breeding and Genetics.* Elsevier, Amsterdam.

Smyth, J.R. Jr. (1994) *Melanin Pigmentation: Its Biological Roles, Inheritance and Expression in the Chicken.* University of Massachusetts, Amherst.

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## Cote (1976) - Self Black Plumage:

Many examples of self black breeds, but similarity is more phenotypic than genotypic. Most are based on E or ER, but not all. Eumelanin enhancing genes found in E & ER based self blacks. Cote (1976) studied nine self black & one birchen male (1976), all carrying eumelanising modifiers. MI found in only 5 out of 9 (ie not in birchen, Black P.Rock, Blue Frizzle & Black OEG). It was linked with the black lacing gene (ie Pg) except in a Mottled Ancona that was homozygous for MI & nonlacing (pg+). Other eumelanin intensifiers were also present, even in the birchen, but they were not identified individually. None of the E heterozygotes developed solid black plumage in the absence of eumelanising modifiers. Eight of the nine males also carried eumelanin restrictors, but only 2 of these carried Co. No birds were carrying Db (tested with Db/Db and Co/Co tester lines)(ed. Crawford, 1990).

## Cote's research birds.....

- 1 Mottled Ancona (EE MI-pg+/MI-pg+ co+/co+ Id w/w)
- 2 Exhibition Barred Plymouth Rock (EE MI-Pg/ml+-pg+ Co/co+ Id w/w)
- 3 Meat type Barred Plymouth Rock (E/eb MI-Pg Co/co+ Id w/w)
- 4 Blue Frizzle Cochin (EE ml+/ml+ co+/co+ Id w/w)
- 5 Meat type Blue (EE MI-Pg co+/co+ Id W+/W+)
- 6 Black Wyandotte (EE MI-Pg co+/co+ Id w/w)
- 7 Solid Black Plymouth Rock (E/eb ml+ Co/co+ id+/id+ w/w)
- 8 Black Old English Game (E/e+ ml+-pg+/ml+-pg+ co+/co+ id+/id+ W+/W+) (plus eumelanisers)
- 9 Birchen Modern Game (EE ml+/ml+ co+/co+ id+/id+ W+/W+)(plus one eumelanin

intensifier)

\* References to Cote's research:

Cote, R.S. (1976). *A genetic analysis of self black plumage color in the domestic fowl*. M.S. Thesis, University of Massachusetts, Amherst.

Crawford, R.D (ed.)(1990). *Poultry Breeding and Genetics*. Elsevier, Amsterdam.

Jeffrey, F.P. (1976) *Bantam Chickens*, ABA .

Smyth, J.R. Jr. (1976) *Genetic Control of Melanin Pigmentation in the Fowl*. University of Massachusetts, Amherst.

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## **Smyth's eb Massachusetts Recessive Black line:**

Totally black, breeds true. Dark Brown down ( $e^b$ ) and white undercolour in the adult males. Shanks and beaks are non-black (Smyth 1976). When crossed to  $e^+/e^+$  and  $e^b/e^b$ , its net effect is “incomplete dominance”. Three and possibly four genes are hypothesised as contributing to the non-E self black plumage (ed. Crawford, 1990).

\* References:

Crawford, R.D (ed.)(1990). *Poultry Breeding and Genetics*. Elsevier, Amsterdam.

Smyth, J.R. Jr. (1976) *Genetic Control of Melanin Pigmentation in the Fowl*. Proc. 25th Poultry Breeder's Roundtable (Kansas City), 69-86.

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## **Fred Jeffrey - Old English Games & eumelanisers:**

Jeffrey, 1988 – Brassy Back & Quail OEG are  $e^+e^+$  , plus autosomal recessive eumelanin enhancer (the Quails also with Co). This eumelanin enhancer darkens the chick down significantly, and produces a purplish-black hue in the down. The Ml gene (on its own) does not change the chick down. Jeffrey produced solid black male birds with this eumelanin enhancer & wheaten, but hens were black with gold lacing.

Fred Jeffrey used the term “hypothetical ebonies” for unknown eumelanin enhancers. Other genes

have been suggested, eg sg (eg, listed by Dr Hollander on his [chicken color genetics chart](#) - but used sg as a replacement for MI) & mi, but mi later believed by Smyth not a new gene, but the effects of Db (Smyth & Malone, 1979). Db (Dark Brown, Columbian-like restrictor) is another sex-influenced autosomal gene, but this time, acts dominant in E<sup>R</sup> males (ie, only one dose needed for expression- Db/db<sup>+</sup>) and recessive in females (2 doses needed for expression). You can see how this could be misinterpreted as a recessive eumelanin enhancer.

#### References:

Crawford, R.D (ed.)(1990). *Poultry Breeding and Genetics*. Elsevier, Amsterdam.

Jeffrey, F.P. (1976) *Bantam Chickens*, ABA .

Jeffrey, F.P. (1988) *Crow wing and recessive black in Old English Game bantams*. ABA Yearbook, Amherst, MA.

Jeffrey, F.P. & Richardson, W. (1995) *Old English Game Bantams as Bred and Shown in the United States*. ABA.

Smyth, J.R., Jr and G.W. Malone, (1979). *Evidence that plumage color genes mi and Db are identical*. Poultry Sci. 58:1108-1109 (Abstract).

Washburn, K.W., & J.R. Smyth Jr., (1967). *A gene for partial feather achromatosis in the fowl*. J. Hered. 58:130-134.

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It can be difficult determining new eumelanin enhancers. Both Melanotic & Charcoal genes were identified as different, by using linkage relationships. They are both on the same chromosome, but different distances to other known loci (eg P) on the same chromosome. The Massachusetts Recessive Black line (e<sup>b</sup> based, not E or E<sup>R</sup>) has 3, or possibly 4 genes contributing to the all black plumage. So there are obviously more eumelanin enhancers that have not been formally described by scientists. Cote found other eumelanin enhancers, other than MI in his studies (including in a Birchen Modern Game). E black lines usually have eumelanin enhancers also.



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## Eumelanin restrictors (Columbian restrictors, restricting black

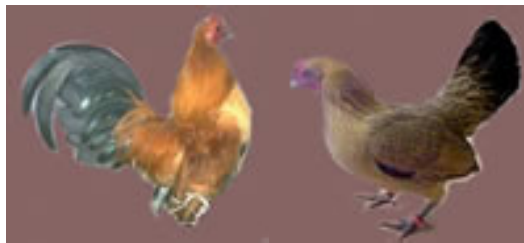
## areas) (Co, Db, Mh, Di)

\* Images used in the following photos are from [Feathersite](#), and the [OEGBCA](#) website.

All these genes not only extend pheomelanin into typical eumelanin areas (Columbian restrictors), but also change the shade of pheomelanin- dilute or darken the gold at various levels.



Co -Columbian



Db - Dark Brown

The Db gene is unusual in that when homozygous, it is a very good columbian restrictor in males, yet only a partial columbian restrictor in females. The Db/Db male phenotype is black-tailed red (black-tailed silver if S/S), with  $e^+$ ,  $eb$ ,  $ER$ , etc alleles. There is a European breed, Villafranguina ( $eb/eb$  Db/Db), which has the Black-tailed Red male & secondary patterned female phenotype. The Db gene has little effect on salmon colouring in  $e^+$  &  $e^{Wh}$  hens, diluting the colour slightly (Smyth) (Dr Okimoto's personal experience is that Db slightly intensifies the salmon shade).

The Db gene (when homozygous) significantly changes chick down pattern/colour, in all E locus alleles, except for  $e^{Wh}$ . This gene was named after its trait of modifying  $ER$  - black down to brown shades (in some genotypes, the brown may be restricted to the head region- i.e. black body unchanged). With  $e^+$  and  $eb$ , the Db gene modifies pheomelanin shade to very pale gold-brown to cream/white, & modifies dorsal striping pattern on the back & head - widens light stripes on the back, & may reduce/fade "arrow-head" stripe on the head. Juvenile pheomelanin feathers of  $e^+/e^+$  Db/Db may appear at first quite pale on the body & wings, contrasting with salmon-red shades on the breast (for both males & females). In juveniles, a poor autosomal barring pattern may be observed on the top/wings, this generally fading with adult plumage (unless modifiers are present, eg Pg). The following link is of an  [\$e^+/e^+\$  Db/? rooster](#), from day-old through to adulthood (note, this rooster also has other eumelanin modifiers present).

Db is linked to M1 - 12cM (approx 22cM to Pg & 32cM to P), i.e., the linkages in order along the

chromosome are **P-32-Db-12-MI-10-Pg**.

\*Note, heterozygous  $e^+/e^+$  Co/co<sup>+</sup> hens may appear similar in phenotype to  $e^+/e^+$  Db/Db hens, ie appear similar to Ginger Red phenotype.



Mh - Mahogany

\* note, the above Welsumers have characteristics similar to Mh traits, but I don't know if it has been substantiated whether this is due to the Mh gene.



Di - Dilute (& possibly eWh Co Db Mh)

\* note, a solid buff/red phenotype may be produced various ways. The above birds may or may not have Di (or Db), although both Mh & Di were extracted from a solid Buff Minorca bird by Brumbaugh & Hollander. This Buff Minorca bird's genotype was determined to be:  
 **$e^y$  or  $e^{bc}/?$  Di/Di Co/Co Mh/Mh db<sup>+</sup>/db<sup>+</sup>, plus possibly Cb.**

## Undercolour: (by Dr Okimoto)

Wheaten has a cream feather undercolor.  $e^+$  and  $e^b$  have a gray feather undercolor even in the presence of Co.  $e^Whe^+$  CoCo<sup>+</sup> heterozygotes have the gray feather undercolor and birds that I have that are  $e^Wheb$  CoCo (I crossed a New Hamp to a Columbian Wyandotte) also have the gray feather undercolor, but it is lighter and looks more silvery than gray. If you find that your birds are  $e^Wheb$  and they have a white or cream feather undercolor they may have melanotic. Birds with melanotic often have a white feather undercolor, but this may be an interaction with some other genes because I don't think that they all have a white undercolor.





## Secondary Pattern Genes



(Pg, MI, Db, mo, B, B<sup>Sd</sup>, Co, Db, Erminette (Er) )









### Secondary Patterns based on:

Pg- Pattern gene, MI- Melanotic, Co- Columbian, Db - Dark Brown

\* Images used in the following photos are from [Feathersite](#), and the [OEGBCA](#) website.

\* Note, the following are only base genotypes. Both Smyth & Carefoot have indicated that their proposed genotypes of secondary patterned varieties (with Pg, etc) are the BASE genotypes for these varieties. They have noted what genes have segregated from test breeding (including linkage testing), but admit freely that there are other modifiers needed to produce exhibition quality birds.

Photo	Hen Phenotype	Genotype	Added mutation from previous variety
	e <sup>b</sup> - Brown based - stippling	e <sup>b</sup> e <sup>b</sup>	e <sup>b</sup> - Brown
	Concentric Pencilling	e <sup>b</sup> e <sup>b</sup> PgPg	Pg - pattern gene

	Double Lacing	$e^{be^b}$ PgPg MIMI	MI - Melanotic
	Single Lacing	$e^{be^b}$ PgPg MIMI CoCo	Co - Columbian
			
	ER- Birchen based	$E^R E^R$	$E^R$ - Birchen
	Autosomal Barring	$E^R E^R$ PgPg DbDb	Pg, Db - Dark Brown,
	Spangled	$E^R E^R$ PgPg DbDb MIMI	MI - Melanotic
	Single-laced	$E^R E^R$ PgPg DbDb MIMI CoCo	Co - Columbian
			

















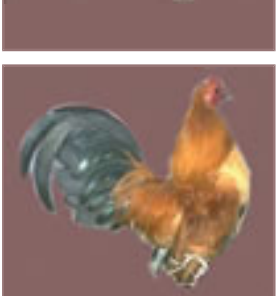
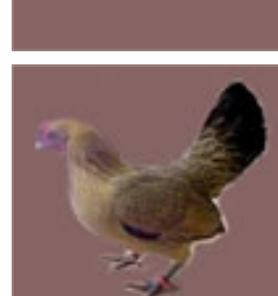


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The following table lists the most common secondary pattern genotypes:

\* click the images to enlarge



\* Images used in the following photos are from [Feathersite](#), the [OEGBCA](#) website & Dr Corti's [website](#) (Erminette image).

Phenotype	Pattern	Genotype	Breed/ Variety	Comments	
<b>e<sup>b</sup> (Brown) based varieties:</b>					
		eb hens, stippling on back & body.	e <sup>b</sup> - plus red enhancer(s)	Dark Brown Leghorn	- plus red enhancer(s)
		Concentric Pencilling	e <sup>b</sup> Pg	Partridge Wyandotte Brahmas, Cochin, etc	-
		Double- laced	1: e <sup>b</sup> Pg MI  2: e <sup>Wh</sup> Pg MI Cha*  3: e <sup>y</sup> Pg MI Cha*	1: Barnevelder- Dark 2 & 3: Indian Games - Dark	-both Smyth & Carefoot segregated e <sup>Wh</sup> in Indian Games/ Cornish lines, but other alleles have been noted (e <sup>y</sup> - Morejohn, plus wildtype & dark brown downs) *Indian Games have an extra neck eumelaniser, possibly Cha.

		Buff Columbian	$e^b Co$	Buff Columbian Wyandotte, Brahma, etc	-
		Single Laced	$e^b Pg MI Co$	Gold Laced Wyandotte, Cochin, etc	-
		Melanised Co- Quail	$e^b MI Co$	Quail Belgian Barbu Bantams	also: $e^+ MI Co$ , $e^{Wh} MI Co$ , or another eumelanin enhancer
		Melanised Co-Vorwerk	$e^b Co +$ eumelanin enhancer(s)	Vorwerk or Golden Lakenvelder	? Charcoal ? Melanotic
		Black Tailed Red male-stippled hen	$e^b Db$	Villafranquina	similar to Ginger Red variety ( $e^+ Db$ ) - photos are Ginger Reds - $e^+$
		Black Tailed Red male-autosomal barred hen	$e^b Pg Db$	Gold Pencilled Hamburg	-

		Black-Tailed Red male-buttercup hen	$e^{bc}$ or $e^b$ Pg Db	Silician Buttercup	Recent DNA sequencing has indicated that this variety may not be $e^{bc}$ , but $e^b$ with other modifiers
		Black Tailed Red	<p>1: <math>e^{Wh}</math> Db Co ?</p> <p>* possibly Mh</p> <p>2: <math>e^y</math> Co Mh</p> <p>3: <math>e^{Wh}</math> Co Mh</p>	<p>Black Tailed Red</p> <p>1: Old English Game</p> <p>2: Rhode Island Red</p> <p>3: New Hampshire</p>	This variety can be developed without Db - eg Rhode.I.Red - red enhancers
		Mottled Buff Columbian	$e^b$ Co mo	<p>Millefleur</p> <p>Belgian Barbu</p> <p>Bantams, Dutch Booted, Pekins, Speckled Sussex</p>	-may also be $e^{Wh}$ , $e^+$ based

**$E^R$  Birchen based varieties:**

		Brown Red	$E^R$	Brown Red Marans	-not necessarily with gold breast lacing, as the genetics of the lacing is not known
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Black  
Tailed Red  
male-  
autosomal  
barred hen

$E^R$  Fayoumi Pg  
Db

\* Smyth  
believed these  
had Co.  
\* Carefoot  
found no Co in  
his stock (ie co  
+).

Fayoumi

- note, the photos  
are of sex-linked  
silver versions,  
not gold.



Autosomal  
barred,  
both  
genders

$E^R$  Pg Db Hf

Campine

- henny-  
feathered



Gold  
Spangled-  
both  
genders

$E^R$  Pg MI Db

Gold  
Spangled  
Hamburg

-sometimes  
henny feathered -  
Hf



Single  
Laced  
-both  
genders

$E^R$  Pg MI Db  
Co Hf

Gold Laced  
Sebright

-possibly  
Polish Laced  
varieties

- henny feathered




Black  
Mottled



$E^R$  mo  
+ eumelanin  
extenders (eg  
MI)



Black  
Mottled  
Ancona

- may also be E -  
Extended Black  
based

	Laced Blue (Blue Andalusian)	$E^R B1/bl+$ Pg MI (Co) + eumelanin extenders	Blue Andalusion	- may also be E - Extended Black based -Carefoot found Co, but Campo et. al. found $co^+$
	Non-laced Blue	$E^R B1/bl+$ + eumelanin extenders (eg MI)	UK Blue Leghorn, UK Blue Wyandotte, Spanish Blue Andalusian, etc.	- may also be E - Extended Black based *note, this is not lav - Lavender
	Sex-linked Dilution	$E^R B^{Sd}$ + eumelanin extenders (eg MI)	California Grey	- may also be E - homozygous $B^{Sd}/B^{Sd}$ males are white.
	Sex-linked Barred	$E^R B$ + eumelanin extenders (eg MI)	Cuckoo	- may also be E - Extended Black based

**$e^+$  wild type based varieties:**

	Barred wild type	$e^+ B$	Crele Old English Game	-
	Mottled wild type	$e^+ mo$	Spangled Old English Game, Mottled Brown Leghorn, etc	- Spangled also with pheomelanin enhancers

		Melanised wild type	$e^+ MI$	Brassy Back Old English Game	- may also be other eumelanin enhancers, eg Cha, etc.
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**Miscellaneous varieties:**

		Buff	$eWh Co Mh Di$	Buff Orpington Buff Minorca	-may also be other E locus alleles, plus Db, Cb.
		Erminette	$E Er$	Erminette	-Incomplete Dominant. -Er/Er are white.

**Heterozygous Pg and MI on eb Co base:**

Moore & Smyth (1972) found that **by itself the pattern gene caused an incomplete lace – restricted to the distal tip of the feather**. Melanotic (MI) was required to complete the lace, with the two genes functioning dose dependently. The following diagram is based on a drawing from the following article by Smyth: *Genetic Control of Melanin Pigmentation in the Fowl* (1976).

This is what they segregated from test breeding Silver Laced Wyandottes (from memory, to an eb test line?): The following are eb Co based:



Pg-MI/pg<sup>+</sup>-ml<sup>+</sup>



Pg-MI/pg<sup>+</sup>-MI



Pg-MI/Pg-ml<sup>+</sup>



Pg-MI/Pg-MI

**\*Smyth (1976):  
Lacing (Pg) alone results in a black tip.**

\* Note, I've changed Lg (from the original drawing) to Pg (& I've changed ground colour from silver to gold).

So heterozygous Pg-MI/pg<sup>+</sup>-ml<sup>+</sup> on Co looks similar to spangling, & Pg/Pg on Co produces an incomplete lace on the tip of the feather.







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## Eumelanin diluters (Bl, lav, l, l<sup>D</sup>, l<sup>S</sup>, choc, c)

These genes alter the eumelanin- black areas of the wild type. Some genes change both eumelanin & pheomelanin pigment (eg Lavender, Recessive White, etc).

\* Images used in the following table are from [Feathersite](#), and the [OEGBCA](#) website, except the Smoky image (from Dr Ron Okimoto), Lavender OEGB image from Al Zwick, photo also found at [Yahoo Poultry Genetics](#) website, and the sex-linked Chocolate image ( breeder: Dr WC Carefoot, photo supplied

by Dr Corti, at the following [website](#)).

Photo	Name	Gene	Inheritance Mode	Comments
	Blue/ Splash	Bl	Autosomal Incomplete Dominant	Heterozygous- Blue Homozygous- Splash
	Lavender	lav	Autosomal Recessive	Also dilutes pheomelanin
	Dominant White	I	Autosomal Incomplete Dominant	Fades pheomelanin when homozygous , but not with one dose.
	Dun	I <sup>D</sup>	Autosomal Incomplete Dominant	One dose darker than two doses. Allelic to I

	Smoky	$I^S$	Autosomal Both Dominant & Recessive	Changes eumelanin - black to smoky shade. One dose visible in chick down-bluish, but two doses needed for adult plumage expression. Allelic to I (Dominant to I).
	Sex-linked Chocolate	choc	Sex-Linked, recessive	Changes black-eumelanin to a chocolate-brown shade
	Recessive White	c	Autosomal recessive	Changes both pheomelanin & eumelanin to white

## Miscellaneous Eumelanin inhibitors/diluters:

### Recessive White Locus:

Recessive White (c) relates to Tyrosinase in chickens.

There are a few alleles on the c locus, eg c,  $c^{re}$ ,  $c^a$

- Recessive White (c),
- Recessive White -Red Eyed ( $c^{re}$ ),
- Albinism ( $c^a$ )

The  $c^{re}$  have very dark red eyes, usually only noticable by shining light into the eyes. The typical

recessive whites - c have dark eyes.

## Sex-Linked Silver Locus ( $s^{al}$ mutations):

There is also a sex-linked imperfect albinism ( $s^{al}$ ) mutation, proposed to be on the S (silver) locus. This one changes eye pigment to pinkish- through to red. E birds, both down & adult plumage, are changed to "light greyish tan", while red columbian birds -down is changed to "creamy", with adults "tinge with red". Order of dominance on the S locus is: S,  $s^+$ ,  $s^{al}$ , i.e.  $s^{al}$  is recessive to the wild type sex-linked gold gene. Silversides & Crawford (1991) also noted another allele, a mutation that occurred at the University of Saskatchewan , i.e sex-linked imperfect albinism:  $S^{al-s}$

Both  $c^a$  and  $s^{al}$  albinos have health associated problems (eg, eyesight problems, higher embryo mortality rates, etc).

### References:

Crawford, R.D (ed.)(1990). *Poultry Breeding and Genetics*. Elsevier, Amsterdam.

Silversides F.G, Crawford R.D. (1991). *Phenotypic, embryonic, and neonatal effects of a gene for sex-linked imperfect albinism ( $S^{al-s}$ ) in chickens*. *Poult Sci*. 1991 Jun;70(6):1306-13.

## Pink Eye (pk):

An autosomal recessive gene. Eye colour appears pink and the plumage colour appeared blue in the birds studied by Warren (1940). The mutation was first found in White Plymouth Rocks by Warren, and later found in another flock of White Plymouth Rocks by Roberts et. al., in 1952. The mutation doesn't appear to modify pheomelanin.

### References:

Crawford, R.D (ed.)(1990). *Poultry Breeding and Genetics*. Elsevier, Amsterdam.

Hutt, F (1949) *Genetics of the Fowl* .

## Grey:

The following description from "Poultry Breeding & Genetics".

**"Grey: - autosomal recessive, dilutes black to light to dark brownish-grey. In older birds, the colour bleached to a dirty yellow."**

### Reference:

Erasmus, J.E., & Liebenberg, C.R. (1958). *A New Mutant in Feather Colour of the South African Black Australorp*. *S. Afr. J. Agric. Sci.* 1:227-230.

The mutation occurred in South Africa.

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## Dun ( $I^D$ ) and Sex-linked Chocolate (choc):

There are at least two different genes that give a chocolate phenotype, ie Dun ( $I^D$ ) and Chocolate (choc). Here is a little history on Carefoot's Chocolate Orpingtons..

\* translated from Italian -Dr Corti's website Vol 3 -V 12. Cioccolato quote:

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The change chocolate in the chicken was observed for the first time in 1994, and precisely from Clive Carefoot in its breeding - - -. In 1996 Carefoot it confided an its large disappointment: although had wanted to put itself repeatedly in contact with an Australian breeder than perhaps had observant in the chicken the same change, not ever some ricevette reply. The disappointment was had to to the fact that Carefoot did not want absolutely to attribute itself the fatherhood of a verification already done from other.

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So the chocolate gene is a relatively new mutation, first observed by Carefoot in 1994. As the chocolate gene is sex-linked recessive, it will breed true to type. Yet the Dun gene ( $I^D$ ) is similar to Blue (Bl), ie incompletely dominant, where heterozygotes ( $I^D/i^+$ ) produce a darker Dun colour, yet the homozygotes ( $I^D/I^D$ ) produce a much paler Dun colour. The Dun genetics are explained at [MSN Polish Chickens website](#):

The difference in Dun expression are shown in the OEGB varieties:

[OEGB: Fawn \(Dun homozygote  \$I^D/I^D\$ \)](#)

[Fawn Silver Duckwing \(Dun heterozygote  \$I^D/i^+\$ \)](#)

Dan has written an article at S.P.P.A, explaining the differences between Dun & Blue:

<http://groups.msn.com/SPPA/dunvsblue101.msnw>

Dun seems to have variation in expression, from bluish-dun to a hint of chocolate in others. The following Fawn Breasted Red OEGB appears more blue than chocolate, yet another example of heterozygous  $I^D$ .

[Fawn Breasted Red OEGB \(Heterozygous  \$I^D/i^+\$ \)](#)

\* Dr Okimoto has mentioned in the past that red enhancers may modify Dun expression.

The Dun gene is an allele of the Dominant White (I) locus. The Dun gene ( $I^D$ ) is found in various breeds in the US, but unfortunately given several different variety names, eg "Fawn" in OEGB, "Chocolate & Khaki" in Polish, "Dun" in Wyandottes, etc. So the reference to "Chocolate" in Dun Polish, etc may cause some confusion in the future, if/once the sex-linked Chocolate (choc) stock becomes available for distribution (I'm not aware if Dr Carefoot has released stock to date). Going by the photos I've seen of Chocolate Orpingtons & Dun birds, the Chocolates (choc) seem to have a glossy sheen to them & a richer chocolate colour (no slate-dun shades, as found in  $I^D$ ).

\* P.S. I'm not aware of what chocolate-like birds in Australia that were referred to by Carefoot. There are brown breasted birds, eg "Brown Breasted Brown Reds", "Brown Breasted Birchen Duckwings" etc, that are a dull mustard brown shade. But I haven't been able to find out their genetics. It doesn't appear like the colour of Carefoot's Chocolate Orpingtons. I've also seen brown laced gold birds in Australian Pit Game Bantams, I imagine the same brown breasted gene(s) involved. The following is a Brown-breasted Brown Red (?) Australian Pit Game Bantam:



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## Pheomelanin Intensifiers and Diluters

\* Images used in the following examples are from [Feathersite](#), and the [OEGBCA](#) website.

The following groups influence the ground colour (pheomelanin), at various levels:

- S locus (Sex-linked Gold or Sex-linked Silver),
- Pheomelanin Diluters (eg. Cream, Dilute, Champagne Blonde, etc)
- Red Intensifiers (eg. Mahogany, Dk, Dk1, etc)
- Eumelanin Restrictors (eg. Columbian, Dark Brown, Dilute, Mahogany, etc)
- Eumelanin diluters (eg. Dominant White, Lavender, Blue)
- Slow feathering genes (K is believed to intensify red)
- E locus (eg, Wheaten alleles tend to be intensified more than other alleles when in combination

with Mh)

- Hormonal influences (eg, females darken as they age, & in some instances remain darker than roosters)

### Eumelanin Diluters:



\* Left: Black, Middle: Blue- Bl, Right: Lavender- lav

I've noticed the blue gene seems to dilute the pheomelanin ground colour some, but not to the extreme of homozygous Dominant White or Lavender. Heterozygous Dominant White (I/i+) doesn't change pheomelanin, but homozygous Dominant White fades the expression of pheomelanin. Lavender (lav/lav) dilutes the expression of pheomelanin dramatically to a straw-cream shade.

### Columbian Restrictors :



One other point is the influence of columbian restrictors on gold. The Columbian gene lightens the red of the wild type (eg Black Red- partridge, or Black Breasted Red) to an orangy colour. Yet the Dark Brown gene tends to keep the pheomelanin a richer burnt orange-red colour.

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### Red Intensifiers:

**Mh (Mahogany)** characteristics;



- -incompletely dominant
- -a partial eumelanin restriction, especially in back, breast & wing plumage (male homozygote resembling the spangling pattern on breast),
- -down colour not effected (eg, pheomelanin not darkened in chicks),
- -1st isolated from Buff Minorcas.

**Dk, Dk1** characteristics (proposed by Kimball, 1955, but not substantiated):



- An allelemorphic series (ie, all alleles on the same locus)
- -Dominant
- Dk present in Spangled Game, Partridge varieties & Dark Cornish (Indian Games)
- Dk1 present in Dark Brown Leghorns

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### Gold Diluters:

### Sex-linked Silver:



\* Sex-linked Silver on e<sup>+</sup> wild type

The Sex-linked Silver gene (S) changes most of the pheomelanin (gold-red) of the wild type phenotype to silver-white, except for the salmon breast of the hens. This gene is incompletely dominant in the males.

### Di (Dilute) characteristics;





\*note, the above phenotype is an accumulation of columbian-like restrictors (eg, Co, & other possibilities such as Di, etc)

- -incompletely dominant
- -dilution of pheomelanin in adult plumage (gold-red)
- -dilution of chicken down (in pheomelanin),
- -reduction of lateral stripes on wild type down (stripes remained in the head & eye area),
- -dilution of dermal pigment (id+), &
- -a partial eumelanin restrictor.

### **Cb (Champagne Blonde ) characteristics;**

- -dominant
- -might have a close linkage with Columbian,
- -not supposed to dilute down (pheomelanin) &
- -no change to down pattern.

\* It appears there was a mix up at one stage, as both Carefoot & Jeffrey printed the gene as recessive, yet it is believed to be dominant by the researchers who segregated Cb.

### **ig (Inhibitor of Gold - Cream ) characteristics;**



- -recessive,
- -no effect on eumelanin
- -generally males show a greater dilution of pheomelanin than females
- - Smyth has noted that it doesn't dilute down (pheomelanin)

\* The British Poultry Standards of the Cream Legbar chicken down (says to refer to the Silver Legbars for description), suggests the down is diluted dramatically. So it would be interesting to read Punnett's & Taylor's research, to see if a description is given for ig chick down.

\*A gold diluted phenotype in my d'Uccles, looks very similar to the cream (ig) phenotype in European d'Uccles (ie, Lemon/Citron Millefleur), although the roosters have adult plumage similar shade of gold to the hens (ig males are lighter silvery/gold phenotype to the gold females). But in my d'Uccles the chick down (pheomelanin only) is diluted dramatically (appearing very similar to silver).



The first feathers appear silvery/very light-gold but darken into patches of gold (see below) at about 3 months on - and into a more even shade of lemon (similar to European Citron Millefleur) at adulthood.



The gold diluter has no effect on id+ slate/blue leg colour, and appears to be a recessive gene.

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Kimball (1955) reported another recessive gold diluter (isolated from lemon-buff & pale gold-laced Wyandottes) that is believed different to ig.



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**-End of Page 1 (of 3) Poultry Mutations-**

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- Page 3: Genes Tables

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