

|                                                                                                                                                                                                                |                |              |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|--------------|
|                                                                                                                                                                                                                | Gephebase Gene | GepheID      |
| MC1R ( <a href="https://www.gephebase.org/search-criteria?/and+GeneGephebase=~MC1R~#gephebase-summary-title">https://www.gephebase.org/search-criteria?/and+GeneGephebase=~MC1R~#gephebase-summary-title</a> ) | GP00001367     | Main curator |
|                                                                                                                                                                                                                | Entry Status   | Courtier     |
| Published                                                                                                                                                                                                      |                |              |

|                                                                                                                                                                                                                                                 | Trait Category         |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|
| Morphology ( <a href="https://www.gephebase.org/search-criteria?/and+Trait+Category=~Morphology~#gephebase-summary-title">https://www.gephebase.org/search-criteria?/and+Trait+Category=~Morphology~#gephebase-summary-title</a> )              | Trait                  |
| Coloration (feathers) ( <a href="https://www.gephebase.org/search-criteria?/and+Trait=~Coloration(feathers)~#gephebase-summary-title">https://www.gephebase.org/search-criteria?/and+Trait=~Coloration(feathers)~#gephebase-summary-title</a> ) | Trait State in Taxon A |
| Toucans (Ramphastidae)                                                                                                                                                                                                                          | Trait State in Taxon B |
| toucans Ramphastos (Ramphastidae) with largely black plumage                                                                                                                                                                                    | Ancestral State        |
| Taxon A                                                                                                                                                                                                                                         | Taxonomic Status       |
| Interspecific ( <a href="https://www.gephebase.org/search-criteria?/and+Taxonomic+Status=~Interspecific~#gephebase-summary-title">https://www.gephebase.org/search-criteria?/and+Taxonomic+Status=~Interspecific~#gephebase-summary-title</a> ) |                        |

| Taxon A                                                                                                                                                                                                                                                                                                                                                     |                             |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| Ramphastidae                                                                                                                                                                                                                                                                                                                                                | Latin Name                  |
| ( <a href="https://www.gephebase.org/search-criteria?/and+Taxon and Synonyms=~Ramphastidae~#gephebase-summary-title">https://www.gephebase.org/search-criteria?/and+Taxon and Synonyms=~Ramphastidae~#gephebase-summary-title</a> )                                                                                                                         |                             |
| -                                                                                                                                                                                                                                                                                                                                                           | Common Name                 |
| -                                                                                                                                                                                                                                                                                                                                                           | Synonyms                    |
| family                                                                                                                                                                                                                                                                                                                                                      | Rank                        |
| cellular organisms; Eukaryota; Opisthokonta; Metazoa; Eumetazoa; Bilateria; Deuterostomia; Chordata; Craniata; Vertebrata; Gnathostomata; Teleostomi; Euteleostomi; Sarcopterygii; Dipnotetrapodomorpha; Tetrapoda; Amniota; Sauropsida; Sauria; Archelosauria; Archosauria; Dinosauria; Saurischia; Theropoda; Coelurosauria; Aves; Neognathae; Piciformes | Lineage                     |
| Piciformes () - (Rank: order)                                                                                                                                                                                                                                                                                                                               | Parent                      |
| ( <a href="https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id= 9219">https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id= 9219</a> )                                                                                                                                                                                                       | NCBI Taxonomy ID            |
| 57381                                                                                                                                                                                                                                                                                                                                                       |                             |
| ( <a href="https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id= 57381">https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id= 57381</a> )                                                                                                                                                                                                     |                             |
| No                                                                                                                                                                                                                                                                                                                                                          | is Taxon A an Intraspecies? |

| Taxon B #1                                                                                                                                                                                                                                                                                                                                                                            |                             |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
|                                                                                                                                                                                                                                                                                                                                                                                       | Latin Name                  |
| Ramphastos dicolorus                                                                                                                                                                                                                                                                                                                                                                  |                             |
| ( <a +ramphastos="" dicolorus`#gephebase-summary-title"="" href="https://www.gephebase.org/search-criteria?/and+Taxon and Synonyms=">https://www.gephebase.org/search-criteria?/and+Taxon and Synonyms="+Ramphastos dicolorus`#gephebase-summary-title</a> )                                                                                                                          |                             |
|                                                                                                                                                                                                                                                                                                                                                                                       | Common Name                 |
| -                                                                                                                                                                                                                                                                                                                                                                                     |                             |
|                                                                                                                                                                                                                                                                                                                                                                                       | Synonyms                    |
| -                                                                                                                                                                                                                                                                                                                                                                                     |                             |
|                                                                                                                                                                                                                                                                                                                                                                                       | Rank                        |
| species                                                                                                                                                                                                                                                                                                                                                                               |                             |
|                                                                                                                                                                                                                                                                                                                                                                                       | Lineage                     |
| cellular organisms; Eukaryota; Opisthokonta; Metazoa; Eumetazoa; Bilateria; Deuterostomia; Chordata; Craniata; Vertebrata; Gnathostomata; Teleostomi; Euteleostomi; Sarcopterygii; Dipnotetrapodomorpha; Tetrapoda; Amniota; Sauropsida; Sauria; Archelosauria; Archosauria; Dinosauria; Saurischia; Theropoda; Coelurosauria; Aves; Neognathae; Piciformes; Ramphastidae; Ramphastos |                             |
|                                                                                                                                                                                                                                                                                                                                                                                       | Parent                      |
| Ramphastos () - (Rank: genus)                                                                                                                                                                                                                                                                                                                                                         |                             |
| ( <a href="https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id= 91780">https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id= 91780</a> )                                                                                                                                                                                                                               | NCBI Taxonomy ID            |
| 322580                                                                                                                                                                                                                                                                                                                                                                                |                             |
| ( <a href="https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id= 322580">https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id= 322580</a> )                                                                                                                                                                                                                             |                             |
|                                                                                                                                                                                                                                                                                                                                                                                       | is Taxon B an Infrappecies? |
| No                                                                                                                                                                                                                                                                                                                                                                                    |                             |

|                                                                                                                                                                                                                                                                                                                                                                                       |                  |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| Taxon B #2                                                                                                                                                                                                                                                                                                                                                                            |                  |
| Ramphastos vitellinus<br>( <a +ramphastos+vitellinus`#gephebase-summary-type"="" href="https://www.gephebase.org/search-criteria?/and+Taxon+and+Synonyms=">https://www.gephebase.org/search-criteria?/and+Taxon+and+Synonyms="+Ramphastos+vitellinus`#gephebase-summary-type</a> )                                                                                                    | Latin Name       |
| -                                                                                                                                                                                                                                                                                                                                                                                     | Common Name      |
| -                                                                                                                                                                                                                                                                                                                                                                                     | Synonyms         |
| species                                                                                                                                                                                                                                                                                                                                                                               | Rank             |
| cellular organisms; Eukaryota; Opisthokonta; Metazoa; Eumetazoa; Bilateria; Deuterostomia; Chordata; Craniata; Vertebrata; Gnathostomata; Teleostomi; Euteleostomi; Sarcopterygii; Dipnotetrapodomorpha; Tetrapoda; Amniota; Sauropsida; Sauria; Archelosauria; Archosauria; Dinosauria; Saurischia; Theropoda; Coelurosauria; Aves; Neognathae; Piciformes; Ramphastidae; Ramphastos | Lineage          |
| Ramphastos () - (Rank: genus)<br>( <a href="https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id=91780">https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id=91780</a> )                                                                                                                                                                                                | Parent           |
|                                                                                                                                                                                                                                                                                                                                                                                       | NCBI Taxonomy ID |

|                                                                                                                                                        |                             |
|--------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| 91793                                                                                                                                                  |                             |
| ( <a href="https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id=91793">https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id= 91793</a> ) |                             |
|                                                                                                                                                        | is Taxon B an Intraspecies? |
| No                                                                                                                                                     |                             |

|                                                                                                                                                                                                                                                                                                                                                                                       |                             |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| Taxon B #3                                                                                                                                                                                                                                                                                                                                                                            |                             |
|                                                                                                                                                                                                                                                                                                                                                                                       | Latin Name                  |
| Ramphastos tucanus                                                                                                                                                                                                                                                                                                                                                                    |                             |
| ( <a +ramphastos="" href="https://www.gephebase.org/search-criteria?/and+Taxon and Synonyms=" tucanus`#gephebase-summary-title"="">https://www.gephebase.org/search-criteria?/and+Taxon and Synonyms="+Ramphastos tucanus`#gephebase-summary-title</a> )                                                                                                                              |                             |
|                                                                                                                                                                                                                                                                                                                                                                                       | Common Name                 |
| -                                                                                                                                                                                                                                                                                                                                                                                     |                             |
|                                                                                                                                                                                                                                                                                                                                                                                       | Synonyms                    |
| red-billed toucan                                                                                                                                                                                                                                                                                                                                                                     |                             |
|                                                                                                                                                                                                                                                                                                                                                                                       | Rank                        |
| species                                                                                                                                                                                                                                                                                                                                                                               |                             |
|                                                                                                                                                                                                                                                                                                                                                                                       | Lineage                     |
| cellular organisms; Eukaryota; Opisthokonta; Metazoa; Eumetazoa; Bilateria; Deuterostomia; Chordata; Craniata; Vertebrata; Gnathostomata; Teleostomi; Euteleostomi; Sarcopterygii; Dipnotetrapodomorpha; Tetrapoda; Amniota; Sauropsida; Sauria; Archelosauria; Archosauria; Dinosauria; Saurischia; Theropoda; Coelurosauria; Aves; Neognathae; Piciformes; Ramphastidae; Ramphastos |                             |
|                                                                                                                                                                                                                                                                                                                                                                                       | Parent                      |
| Ramphastos () - (Rank: genus)                                                                                                                                                                                                                                                                                                                                                         |                             |
| ( <a href="https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id=91780">https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id= 91780</a> )                                                                                                                                                                                                                                |                             |
|                                                                                                                                                                                                                                                                                                                                                                                       | NCBI Taxonomy ID            |
| 125240                                                                                                                                                                                                                                                                                                                                                                                |                             |
| ( <a href="https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id=125240">https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id= 125240</a> )                                                                                                                                                                                                                              |                             |
|                                                                                                                                                                                                                                                                                                                                                                                       | is Taxon B an Intraspecies? |
| No                                                                                                                                                                                                                                                                                                                                                                                    |                             |

|                                                                                                                                                                                                                                                                                                                                                                                       |                             |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| Taxon B #4                                                                                                                                                                                                                                                                                                                                                                            |                             |
|                                                                                                                                                                                                                                                                                                                                                                                       | Latin Name                  |
| Ramphastos toco                                                                                                                                                                                                                                                                                                                                                                       |                             |
| ( <a +ramphastos="" href="https://www.gephebase.org/search-criteria?/and+Taxon and Synonyms=" toco`#gephebase-summary-title"="">https://www.gephebase.org/search-criteria?/and+Taxon and Synonyms="+Ramphastos toco`#gephebase-summary-title</a> )                                                                                                                                    |                             |
|                                                                                                                                                                                                                                                                                                                                                                                       | Common Name                 |
| -                                                                                                                                                                                                                                                                                                                                                                                     |                             |
|                                                                                                                                                                                                                                                                                                                                                                                       | Synonyms                    |
| toco toucan                                                                                                                                                                                                                                                                                                                                                                           |                             |
|                                                                                                                                                                                                                                                                                                                                                                                       | Rank                        |
| species                                                                                                                                                                                                                                                                                                                                                                               |                             |
|                                                                                                                                                                                                                                                                                                                                                                                       | Lineage                     |
| cellular organisms; Eukaryota; Opisthokonta; Metazoa; Eumetazoa; Bilateria; Deuterostomia; Chordata; Craniata; Vertebrata; Gnathostomata; Teleostomi; Euteleostomi; Sarcopterygii; Dipnotetrapodomorpha; Tetrapoda; Amniota; Sauropsida; Sauria; Archelosauria; Archosauria; Dinosauria; Saurischia; Theropoda; Coelurosauria; Aves; Neognathae; Piciformes; Ramphastidae; Ramphastos |                             |
|                                                                                                                                                                                                                                                                                                                                                                                       | Parent                      |
| Ramphastos () - (Rank: genus)                                                                                                                                                                                                                                                                                                                                                         |                             |
| ( <a href="https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id=91780">https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id= 91780</a> )                                                                                                                                                                                                                                |                             |
|                                                                                                                                                                                                                                                                                                                                                                                       | NCBI Taxonomy ID            |
| 95723                                                                                                                                                                                                                                                                                                                                                                                 |                             |
| ( <a href="https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id=95723">https://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?id= 95723</a> )                                                                                                                                                                                                                                |                             |
|                                                                                                                                                                                                                                                                                                                                                                                       | is Taxon B an Intraspecies? |
| No                                                                                                                                                                                                                                                                                                                                                                                    |                             |

GENOTYPIC CHANGE

|                                                                                                                                                                                                                 |                         |                                                                                                                        |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                                                                                                 | Generic Gene Name       | UniProtKB Mus musculus                                                                                                 |
| Mcr                                                                                                                                                                                                             |                         | Q01727 ( <a href="http://www.uniprot.org/uniprot/Q01727">http://www.uniprot.org/uniprot/Q01727</a> )                   |
|                                                                                                                                                                                                                 | Synonyms                | GenebankID or UniProtKB                                                                                                |
| e; Tob; Mcr1; Mshra; Msh-r                                                                                                                                                                                      |                         | KP233054 ( <a href="https://www.ncbi.nlm.nih.gov/nuccore/KP233054">https://www.ncbi.nlm.nih.gov/nuccore/KP233054</a> ) |
|                                                                                                                                                                                                                 | String                  |                                                                                                                        |
| 10090.ENSMUSP00000095929                                                                                                                                                                                        |                         |                                                                                                                        |
| ( <a href="http://string-db.org/newstring.cgi/show_network_section.pl?identifier=10090.ENSMUSP00000095929">http://string-db.org/newstring.cgi/show_network_section.pl?identifier=10090.ENSMUSP00000095929</a> ) |                         |                                                                                                                        |
|                                                                                                                                                                                                                 | Sequence Similarities   |                                                                                                                        |
| Belongs to the G-protein coupled receptor 1 family.                                                                                                                                                             |                         |                                                                                                                        |
|                                                                                                                                                                                                                 | GO - Molecular Function |                                                                                                                        |
| GO:0004977 : melanocortin receptor activity                                                                                                                                                                     |                         |                                                                                                                        |

(<https://www.ebi.ac.uk/QuickGO/term/GO:0004977>)  
GO:0004980 : melanocyte-stimulating hormone receptor activity  
(<https://www.ebi.ac.uk/QuickGO/term/GO:0004980>)  
GO:0031625 : ubiquitin protein ligase binding  
(<https://www.ebi.ac.uk/QuickGO/term/GO:0031625>)  
GO:0042562 : hormone binding (<https://www.ebi.ac.uk/QuickGO/term/GO:0042562>)  
GO - Biological Process

GO:0045944 : positive regulation of transcription by RNA polymerase II  
(<https://www.ebi.ac.uk/QuickGO/term/GO:0045944>)  
GO:0042438 : melanin biosynthetic process  
(<https://www.ebi.ac.uk/QuickGO/term/GO:0042438>)  
GO:0043473 : pigmentation (<https://www.ebi.ac.uk/QuickGO/term/GO:0043473>)  
GO:0051897 : positive regulation of protein kinase B signaling  
(<https://www.ebi.ac.uk/QuickGO/term/GO:0051897>)  
GO:0019233 : sensory perception of pain  
(<https://www.ebi.ac.uk/QuickGO/term/GO:0019233>)  
GO:0007189 : adenylate cyclase-activating G protein-coupled receptor signaling pathway  
(<https://www.ebi.ac.uk/QuickGO/term/GO:0007189>)  
GO:0035556 : intracellular signal transduction  
(<https://www.ebi.ac.uk/QuickGO/term/GO:0035556>)  
GO:0032720 : negative regulation of tumor necrosis factor production  
(<https://www.ebi.ac.uk/QuickGO/term/GO:0032720>)  
GO:0010739 : positive regulation of protein kinase A signaling  
(<https://www.ebi.ac.uk/QuickGO/term/GO:0010739>)  
GO:0090037 : positive regulation of protein kinase C signaling  
(<https://www.ebi.ac.uk/QuickGO/term/GO:0090037>)  
GO:0070914 : UV-damage excision repair  
(<https://www.ebi.ac.uk/QuickGO/term/GO:0070914>)  
GO:2000253 : positive regulation of feeding behavior  
(<https://www.ebi.ac.uk/QuickGO/term/GO:2000253>)  
GO:0060259 : regulation of feeding behavior  
(<https://www.ebi.ac.uk/QuickGO/term/GO:0060259>)

GO - Cellular Component

GO:0016021 : integral component of membrane  
(<https://www.ebi.ac.uk/QuickGO/term/GO:0016021>)  
GO:0005886 : plasma membrane (<https://www.ebi.ac.uk/QuickGO/term/GO:0005886>)

Mutation #1

Presumptive Null

No (<https://www.gephebase.org/search-criteria?/and+Presumptive Null=~No~#gephebase-summary-title>)

Molecular Type

Coding (<https://www.gephebase.org/search-criteria?/and+Molecular Type=~Coding~#gephebase-summary-title>)

Aberration Type

SNP (<https://www.gephebase.org/search-criteria?/and+Aberration Type=~SNP~#gephebase-summary-title>)

SNP Coding Change

Nonsynonymous

Molecular Details of the Mutation

R112H

Experimental Evidence

Candidate Gene (<https://www.gephebase.org/search-criteria?/and+Experimental Evidence=~Candidate Gene~#gephebase-summary-title>)

|            | Taxon A | Taxon B | Position |
|------------|---------|---------|----------|
| Codon      | -       | -       | -        |
| Amino-acid | Arg     | His     | 112      |

Evolution of dark colour in toucans (Ramphastidae): a case of molecular adaptation?. (2016) (<https://pubmed.ncbi.nlm.nih.gov/27654325>)

Main Reference

Corso J; Mundy NI; Fagundes NJ; de Freitas TR

Authors

Abstract

In the last decades, researchers have been able to determine the molecular basis of some phenotypes, to test for evidence of natural selection upon them, and to demonstrate that the same genes or genetic pathways can be associated with convergent traits. Colour traits are often subject to natural selection because even small changes in these traits can have a large effect on fitness via camouflage, sexual selection or other mechanisms. The melanocortin-1 receptor locus (MC1R) is frequently associated with intraspecific coat colour variation in vertebrates, but it has been far harder to demonstrate that this locus is involved in adaptive interspecific colour differences. Here, we investigate the contribution of the MC1R gene to the colour diversity found in toucans (Ramphastidae). We found divergent selection on MC1R in the clade represented by the genus Ramphastos and that this coincided with the evolution of darker plumage in members of this genus. Using phylogenetically corrected correlations, we show significant and specific relationships between the rate of nonsynonymous change in MC1R (dN) and plumage darkness across Ramphastidae, and also between the rate of functionally significant amino acid changes in MC1R and plumage darkness. Furthermore, three of the seven amino acid changes in MC1R that occurred in the ancestral Ramphastos branch are associated with melanism in other birds. Taken together, our results suggest that the dark colour of Ramphastos toucans was related to nonsynonymous substitutions in MC1R that may have been subject to positive selection or to a relaxation of selective pressure. These results also demonstrate a quantitative relationship between gene and phenotype evolution, representing an example of how MC1R molecular evolution may affect macroevolution of plumage phenotypes.

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Additional References

Mutation #2

|                                                                                                                                                                                                                                                              |                                   |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|
| No ( <a href="https://www.gephebase.org/search-criteria?/and+Presumptive Null=~No~#gephebase-summary-title">https://www.gephebase.org/search-criteria?/and+Presumptive Null=~No~#gephebase-summary-title</a> )                                               | Presumptive Null                  |
| Coding ( <a href="https://www.gephebase.org/search-criteria?/and+Molecular Type=~Coding~#gephebase-summary-title">https://www.gephebase.org/search-criteria?/and+Molecular Type=~Coding~#gephebase-summary-title</a> )                                       | Molecular Type                    |
| SNP ( <a href="https://www.gephebase.org/search-criteria?/and+Aberration Type=~SNP~#gephebase-summary-title">https://www.gephebase.org/search-criteria?/and+Aberration Type=~SNP~#gephebase-summary-title</a> )                                              | Aberration Type                   |
| Nonsynonymous                                                                                                                                                                                                                                                | SNP Coding Change                 |
| R230C                                                                                                                                                                                                                                                        | Molecular Details of the Mutation |
| Candidate Gene ( <a href="https://www.gephebase.org/search-criteria?/and+Experimental Evidence=~Candidate Gene~#gephebase-summary-title">https://www.gephebase.org/search-criteria?/and+Experimental Evidence=~Candidate Gene~#gephebase-summary-title</a> ) | Experimental Evidence             |

|            | Taxon A | Taxon B | Position |
|------------|---------|---------|----------|
| Codon      | -       | -       | -        |
| Amino-acid | Arg     | Cys     | 230      |

|                                                                                                                                                                                                 |                |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|
| Evolution of dark colour in toucans (Ramphastidae): a case of molecular adaptation?. (2016) ( <a href="https://pubmed.ncbi.nlm.nih.gov/27654325">https://pubmed.ncbi.nlm.nih.gov/27654325</a> ) | Main Reference |
| Corso J; Mundy NI; Fagundes NJ; de Freitas TR                                                                                                                                                   | Authors        |

Abstract

In the last decades, researchers have been able to determine the molecular basis of some phenotypes, to test for evidence of natural selection upon them, and to demonstrate that the same genes or genetic pathways can be associated with convergent traits. Colour traits are often subject to natural selection because even small changes in these traits can have a large effect on fitness via camouflage, sexual selection or other mechanisms. The melanocortin-1 receptor locus (MC1R) is frequently associated with intraspecific coat colour variation in vertebrates, but it has been far harder to demonstrate that this locus is involved in adaptive interspecific colour differences. Here, we investigate the contribution of the MC1R gene to the colour diversity found in toucans (Ramphastidae). We found divergent selection on MC1R in the clade represented by the genus Ramphastos and that this coincided with the evolution of darker plumage in members of this genus. Using phylogenetically corrected correlations, we show significant and specific relationships between the rate of nonsynonymous change in MC1R (dN) and plumage darkness across Ramphastidae, and also between the rate of functionally significant amino acid changes in MC1R and plumage darkness. Furthermore, three of the seven amino acid changes in MC1R that occurred in the ancestral Ramphastos branch are associated with melanism in other birds. Taken together, our results suggest that the dark colour of Ramphastos toucans was related to nonsynonymous substitutions in MC1R that may have been subject to positive selection or to a relaxation of selective pressure. These results also demonstrate a quantitative relationship between gene and phenotype evolution, representing an example of how MC1R molecular evolution may affect macroevolution of plumage phenotypes.

|                                                                                                                                       |                       |
|---------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
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|---------------------------------------------------------------------------------------------------------------------------------------|-----------------------|

Mutation #3

|                                                                                                                                                                                                                                                              |                                   |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|
| No ( <a href="https://www.gephebase.org/search-criteria?/and+Presumptive Null=~No~#gephebase-summary-title">https://www.gephebase.org/search-criteria?/and+Presumptive Null=~No~#gephebase-summary-title</a> )                                               | Presumptive Null                  |
| Coding ( <a href="https://www.gephebase.org/search-criteria?/and+Molecular Type=~Coding~#gephebase-summary-title">https://www.gephebase.org/search-criteria?/and+Molecular Type=~Coding~#gephebase-summary-title</a> )                                       | Molecular Type                    |
| SNP ( <a href="https://www.gephebase.org/search-criteria?/and+Aberration Type=~SNP~#gephebase-summary-title">https://www.gephebase.org/search-criteria?/and+Aberration Type=~SNP~#gephebase-summary-title</a> )                                              | Aberration Type                   |
| Nonsynonymous                                                                                                                                                                                                                                                | SNP Coding Change                 |
| H257R                                                                                                                                                                                                                                                        | Molecular Details of the Mutation |
| Candidate Gene ( <a href="https://www.gephebase.org/search-criteria?/and+Experimental Evidence=~Candidate Gene~#gephebase-summary-title">https://www.gephebase.org/search-criteria?/and+Experimental Evidence=~Candidate Gene~#gephebase-summary-title</a> ) | Experimental Evidence             |

|            | Taxon A | Taxon B | Position |
|------------|---------|---------|----------|
| Codon      | -       | -       | -        |
| Amino-acid | His     | Arg     | 257      |

|                                                                                                                                                                                                 |                |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|
| Evolution of dark colour in toucans (Ramphastidae): a case of molecular adaptation?. (2016) ( <a href="https://pubmed.ncbi.nlm.nih.gov/27654325">https://pubmed.ncbi.nlm.nih.gov/27654325</a> ) | Main Reference |
| Corso J; Mundy NI; Fagundes NJ; de Freitas TR                                                                                                                                                   | Authors        |

Abstract

In the last decades, researchers have been able to determine the molecular basis of some phenotypes, to test for evidence of natural selection upon them, and to demonstrate that the same genes or genetic pathways can be associated with convergent traits. Colour traits are often subject to natural selection because even small changes in these traits can have a large effect on fitness via camouflage, sexual selection or other mechanisms. The melanocortin-1 receptor locus (MC1R) is frequently associated with intraspecific coat colour variation in vertebrates, but it has been far harder to demonstrate that this locus is involved in adaptive interspecific colour differences. Here, we investigate the contribution of the MC1R gene to the colour diversity found in toucans (Ramphastidae). We found divergent selection on MC1R in the clade represented by the genus Ramphastos and that this coincided with the evolution of darker plumage in members of this genus. Using phylogenetically corrected correlations, we show significant and specific relationships between the rate of nonsynonymous change in MC1R (dN) and plumage darkness across Ramphastidae, and also between the rate of functionally significant amino acid changes in MC1R and plumage darkness. Furthermore, three of the seven amino acid changes in MC1R that occurred in the ancestral Ramphastos branch are associated with melanism in other birds. Taken together, our results suggest that the dark colour of Ramphastos toucans was related to nonsynonymous substitutions in MC1R that may have been subject to positive selection or to a relaxation of selective pressure. These results also

demonstrate a quantitative relationship between gene and phenotype evolution, representing an example of how MC1R molecular evolution may affect macroevolution of plumage phenotypes.

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Additional References

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other SNP not predicted for functional effect : E100K and R182H and L188F and V262I