

## *Plasmodium relictum*

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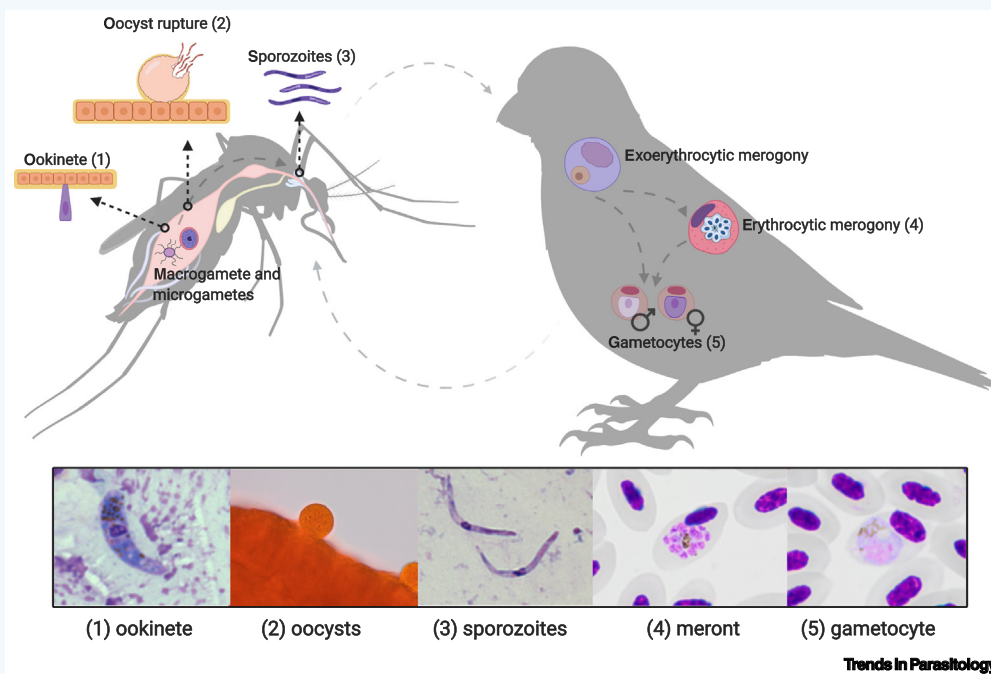
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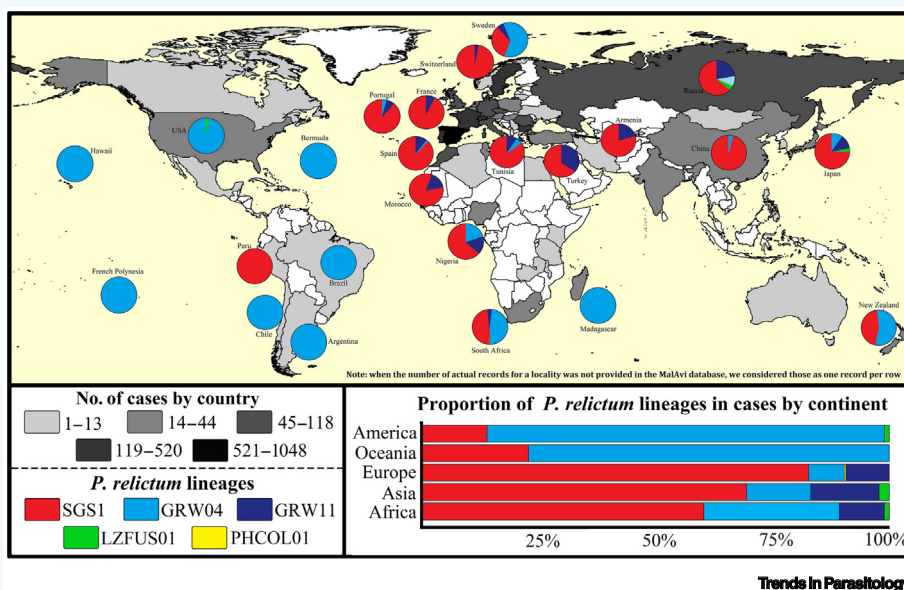
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*Plasmodium relictum* is a widespread haemosporidian parasite infecting over 300 bird species from all continents except Antarctica. Based on sequences of the cytochrome *b* gene, that has become the barcoding region for avian haemosporidians, five different mitochondrial haplotypes (lineages) have been linked to *P. relictum* (SGS1, GRW04, GRW11, LZFUS01, and PHCOL01). *Culex* mosquitoes are the main vectors in *P. relictum* transmission, while other potential vectors include *Aedes*, *Lutzia*, *Culiseta*, and *Anopheles* species. Introduction of the lineage GRW04 to Hawaii in the first half of the 20th century, where *Culex* vectors were previously introduced – in synergy with anthropogenic impacts and infections of other pathogens (i.e., avian pox virus) – resulted in dramatic population declines of native bird species. As a result of this and other invasion events, *P. relictum* is nowadays catalogued as one of the 100 world's worst invasive species.



### KEY FACTS:

Human and avian *Plasmodium* spp. are transmitted by different Culicidae species but have overall similar life cycles between mosquito vector and vertebrate host.

The role of mosquitoes in the transmission of malarial parasites was first demonstrated, using experimental infections of *P. relictum*, by Ronald Ross, who received the Nobel Prize in 1902 for this discovery.

*P. relictum* is one of only two avian *Plasmodium* spp. with sequenced genomes.

*P. relictum* is commonly used as a model organism in ecological and evolutionary experimental studies of malarial parasites.

### DISEASE FACTS:

Molecular tools have identified the lineage SGS1 infecting more species of birds than any other *Plasmodium* lineage.

Unlike most other *Plasmodium* parasites, transmission of *P. relictum* takes place as far north as northern Norway.

In Europe, the findings of the lineage GRW04 are restricted to tropical migratory birds after they return from winter quarters, suggesting the absence of active transmission on breeding grounds.

Infection virulence varies among bird species and transmission areas. Upon infection with *P. relictum*, some bird species (especially in endemic regions) develop light transient parasitemias, while in other species it may lead to acute anemia and organ pathology.

### TAXONOMY AND CLASSIFICATION:

**PHYLUM:** Apicomplexa  
**CLASS:** Aconoidasida  
**ORDER:** Haemosporida  
**FAMILY:** Plasmodiidae  
**GENUS:** *Plasmodium*  
**SPECIES:** *P. relictum*

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## Resources

[www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?l=0&id=85471](http://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi?l=0&id=85471)  
<http://130.235.244.92/Malavi/>

## Literature

1. Asghar, M. *et al.* (2015) Hidden costs of infection: chronic malaria accelerates telomere degradation and senescence in wild birds. *Science* 347, 436–438
2. Bensch, S. *et al.* (2009) MalAvi: a public database of malaria parasites and related haemosporidians in avian hosts based on mitochondrial cytochrome b lineages. *Mol. Ecol. Res.* 9, 1353–1358
3. Gutiérrez-López, R. *et al.* (2020) *Plasmodium* transmission differs between mosquito species and parasite lineages. *Parasitology* 147, 441–447
4. Lowe, S. *et al.* (2000) 100 of the World's Worst Invasive Alien Species. A Selection from the Global Invasive Species Database, The Invasive Species Specialist Group (ISSG; IUCN) 12 pp
5. Martínez-de la Puente, J. *et al.* (2018) Do avian malaria parasites reduce vector longevity? *Curr. Opin. Insect Sci.* 28, 113–117
6. Palinauskas, V. *et al.* (2008) *Plasmodium relictum* (lineage P-SGS1): effects on experimentally infected passerine birds. *Exp. Parasitol.* 120, 372–380
7. Rivero, A. and Gandon, S. (2018) Evolutionary ecology of avian malaria: past to present. *Trends Parasitol.* 34, 712–726
8. Santiago-Alarcon, D. *et al.* (2012) Diptera vectors of avian Haemosporidian parasites: untangling parasite life cycles and their taxonomy. *Biol. Rev.* 87, 928–964
9. Valkiūnas, G. *et al.* (2018) Characterization of *Plasmodium relictum*, a cosmopolitan agent of avian malaria. *Malar. J.* 17, 184
10. van Riper III, C. *et al.* (1986) Epizootiology and ecological significance of malaria in Hawaiian land birds. *Ecol. Monogr.* 56, 327–334