Tapeworms from Vertebrate Bowels of the Earth

—AN OVERVIEW—

Janine N. Caira, Kirsten Jensen, Boyko B. Georgiev, Roman Kuchta, D. Timothy J. Littlewood, Jean Mariaux, Tomáš Scholz, Vasyl V. Tkach, and Andrea Waeschenbach
Project Goals

(1) To discover and describe cestode novelty from
   - as many different countries as possible
   - vertebrate groups not previously examined for cestodes

(2) To recollect from historically problematic regions and/or host taxa to resolve major taxonomic issues

(3) To collect specimens of as many different cestode species across as great a diversity of cestode taxa as possible

(4) To assess interrelationships at multiple levels based on phylogenetic analyses of molecular sequence data from multiple genes informed by morphological data

(5) To attempt to reconcile cestode classification at all levels with a revised understanding of their phylogenetic relationships

(6) To use historical data and new collections to begin to generate estimates of total global diversity
The Team

**Bird-hosted cestode team**
Jean Mariaux & Boyko Georgiev; Eric Hoberg, Vadim Kornyushin, Pavel Nikolov, & Gergana Vasileva

**Mammal-hosted cestode team**
Vasyl Tkach; Ian Beverage, Voitto Haukisalmi, Vadim Kornyushin

**Bony fish-hosted cestode team** (+ holocephalans, “herptiles”)
Tomáš Scholz, Roman Kuchta, & Alain de Chambrier; Alicia Gil de Pertierra, Vladimíra Hanelová, & Mikulas Oros

**Elasmobranch-hosted cestode team**
Janine Caira & Kirsten Jensen; Ian Beverage, Louis Euzet, Claire Healy, Verónica Ivanov, Masoumeh Malek, Fernando Marques, Lassad Neifar, Harry Palm, Florian Reyda, Tim Ruhnke

**Molecular cestode team**
Tim Littlewood & Andrea Waeschenbach
The Team

Program assistant
Elizabeth Barbeau

Project website and databases
Yi Zhang, Josh Roy, & Jason Card

Meet the Suckers children’s book
Virge Kask & Achim Mohrenberg
Training

Postdoctoral fellows

Jitka Aldhoun (Natural History Museum in London)
Jan Brabec (Czech Academy of Sciences)
Joanna Cielocha (University of Kansas; Rockhurst University)
Caroline Fyler (University of Connecticut; Martha’s Vineyard High School)
Voitto Haukisalmi (Finnish Museum of Natural History)
Miloslav Jirků (Czech Academy of Sciences)
Roman Kuchta (Czech Academy of Sciences)
Arseny Makarikov (Russian Academy of Sciences [Siberian Branch])
Adriana Menoret (Universidad de Buenos Aires)
Maria Pickering (University of Connecticut; Meredith College)
Mikulas Oros (Czech Academy of Sciences; Slovak Academy of Sciences)
Martina Orosová (Slovak Academy of Sciences)
Anna Phillips (University of Connecticut; Smithsonian Institution)
Aneta Yoneva (Bulgarian Academy of Sciences)
Andrea Waeschenbach (Natural History Museum in London)

# of postdoctoral fellows: 14

Graduate students

Atabak Aminjan (University of Tehran)
Anirban Ash (Acad. of Sciences of the Czech Republic)
Daniel Barčák (Slovak Academy of Sciences)
James Bernot (University of Connecticut)
Jan Brabeck (Academy of Sciences of the Czech Republic)
Mehdi Golestaninasab (University of Tehran)
Stephen Greiman (University of North Dakota)
Rachel Guyer (University of Kansas)
Mohamed Haseli (University of Tehran)
Kaylee Herzog (University of Kansas)
Kendra Koch (University of Kansas)

# of graduate students: 35

# of undergraduate students: 59
Collaboration!!

Project meetings
Geneva (2009)
Melbourne (2010) (following XIIth ICOPA)
Lawrence (2011) (following 7th IWCSP)
Geneva (2012)
London (2013)
Brazil (2014) (following 8th IWCSP)
The Team

# of participants: >250
Fieldwork

# countries visited: 54
In-country collaborators

Mostafa Hossain (Bangladesh)
Norian Lamb & Roy Polonio (Belize)
Natalia Da Mata Luchetti, Fernando P. L. Marques, Luis Eduardo Tavares, Marcos Tavares, José Luque, & Ricardo Takemoto (Brazil)
Pavel Nikolov (Bulgaria)
Touch Bunthang (Cambodia)
Manigandan Lejeune Virapin (Canada)
Francisco Concha, Günther Försterra, Daniel González-Acuña, & Vreni Häussermann (Chile)
Dian Gao, Cai Kuizheng, Pin Nie, Gui Tang Wang, Shan Gong Wu, & Bing Wen Xi (China)
Tayler Clarke, Ingo Wehrmann, & Mario Espinoza (Costa Rica)
Oscar Carreno & Gabriela Flores (Ecuador)
Mohamed Bosseri & Amal Khalil (Egypt)
Eshete Dejen Dresilign, Abebe Getuhun Gubale, & Seyoum Mengistou (Ethiopia)
Joost Pompert (Falkland Islands)
Bernard Marchand (France)
Mathieu Bourgarel & Jean-Paul Gonzales (Gabon)
Anirban Ash & Pradip K. Kar (India)
Asri Yuinar (Indonesia)
Razieh Ghayoumi & Masoumeh Malek (Iran)
Andrea Gustinelli (Italy)
Inza Kone (Ivory Coast)
Steven Goodman, Marie Jeanne Raherilalao, Jeanne Rasamy, & Achille Raselimanana (Madagascar)
R. Hashim, Susan Lim (late), & R. Ramli (Malaysia)
Samuel Bila (Mozambique)
Jean-Lou Justine (New Caledonia)
Martin Mortenthaler, Aurora Ramírez Aircara, & Lidia Sánchez (Peru)
Rafe Brown (Philippines)
Gracia Costa & Gui Menezes (Portugal)
Vladimir Besprovaznnykh, Vladimir Chistyakov, & Alexey Ermolenko (Russia)
Rokhaya Sall (Senegal)
David Blair, Tingo Leve, & Richard Mounsey (Solomon Islands)
Tracey Fairweather & Robert Leslie (South Africa)
Ki Hong Kim (South Korea)
Zuheir Mahmoud (Sudan)
Hsuan-Ching Ho & Hsuan-Wien Chen (Taiwan)
Lawan Chanhome (Thailand)
Jim Ellis & Andrew Shinn (UK)
Olga Lisitsyna & Yuriy Kvach (Ukraine)
Michael Barger, Megan Bean, Sara Brant, Isaure de Buron, Anindo Choudhury, Joseph Cook, Stephen Curran, Bryan Frazier, Andrew Hope, David G. Huffman, John M. Kinsella, Robin Overstreet, Eric Pulis, & Jason Weckstein (USA)
Tran T. Binh & Vu Quang Manh (Vietnam)
Novelty and Diversity

# of new species: 215
# of new genera: 64
# of new combinations: 135
# of species synonymized: ~200
Novelty and Diversity

# of new species: 215
# of new genera: 64
# of new combinations: 135
# of species synonymized: ~200

<table>
<thead>
<tr>
<th>Cestode order</th>
<th>No. of n. sp.</th>
<th>Cestode order</th>
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### Diversity

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**CURRENT STATUS:**
833 genera
4,810 species
## Diversity

### Cestode order

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### Cyclophyllidean family

<table>
<thead>
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<th>No. of valid genera</th>
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### Onchoproteocephalidea

(by host group)

<table>
<thead>
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<th>Onchoproteocephalidea</th>
<th>No. of valid genera</th>
<th>No. of valid species</th>
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</thead>
<tbody>
<tr>
<td>I: non-elasmobranch</td>
<td>68</td>
<td>316</td>
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<tr>
<td>II: elasmobranch</td>
<td>11</td>
<td>246</td>
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</table>

|                       |                     |                      |
|                       | 6                   | 70                   |
|                       | 25                  | 104                  |
|                       | 81                  | 315                  |
Host Associations

Relative cestode diversity (species) by vertebrate class

CURRENT STATUS: 4,810 species
Host Associations—Poor hosts

Vertebrate groups hosting few or no tapeworms:

- Squamata (snakes and lizards)
- Chelonii (turtles)
- Amphibia (frogs and salamanders)
- Artiodactyla (deer, etc.)
- Perissodactyla (horses, etc.)
- Primata (monkeys, etc.)
- Scombridae (mackerels, tunas, etc.)
- Procellariformes (petrels, etc.)
- Sphenisciformes (penguins)
- Squaliformes (dogfish, etc.)
- "Scyliorhinidae" (cat sharks)
Host Associations—**Good hosts**

Vertebrate groups especially good hosts for tapeworms:

- Soricomorpha (shrews, etc.)
- Chiroptera (bats)
- Lagomorpha (rabbits, etc.)
- Carnivora (bears, etc.)
- Marsupialia (kangaroos, etc.)
- Passeriformes (sparrows, etc.)
- Charadriiformes (plovers, seagulls, etc.)
- Podicipediformes (grebes)
- Anseriformes (ducks, geese, etc.)
- Siluriformes (catfish, etc.)
- Cypriniformes (carp, etc.)
- Myliobatiformes (stingrays, etc.)
- Rhinopristiformes (guitarfish, etc.)
Host Associations—New records

**Bothriocephalidea**
Bothriocephalus sp. from order Lepisosteiformes
New host family records: Archiridae, Bovichtidae, Platycephalidae, & Serranidae

**Diphylleidae**
New host family records: Gurgesiellidae & Proscylliidae

**Lecanicephalidea**
New host family records: Zanobatidae & Urolophidae; + freshwater

**Onchoproteocephalidea I**
New host family records: Gekkonidae and Dactyloidae, Pangasiidae
New genus from Australian endemic frog

**Rhinebothriiidea**
New host family records: Platyrhinidae
Phylogenetics and Classification

# of specimens sequenced: ~1,000
# of orders sequenced: 15/19
loci: 28S rDNA, 18S rDNA, COI, 16S rDNA
taxon coverage (by order): 10–80%

- Bothriocephalidea: 44%
- Caryophyllideae: 80%
- Cathetocephalidea: 75%
- Cyclophyllideae (incl. Mesoc.): 10%
- Diphylleida: 52%
- Diphyllobothriidea: 36%
- Lecanicephalidea: 26%
- Litobothriidea: 55%
- Nippotaeniidea: 57%
- Onchoproteocephalidea: 35%/12%
- Phyllobothriidea: 29%
- Rhinebothriidea: 37%
- Tetrabothriidea: (few)
- “Tetraphyllidea” relics: 33%
- Trypanorhynchophiia: 33%
**Phylogenetics**

**Novel phylogenetic frameworks:**

Bothriocephalidea

Caryophyllidea

Cyclophyllidea

Diphyllidea

Diphyllobothriidea

Lecanicephalidea

Litobothriidea

Onchoproteocephalidea

Phyllobothriidea

Rhinebothriidea

“Tetraphyllidea” relics

Trypanorhynchia


Phylogenetics and Classification

New orders:
- Phyllobothriidea
- Onchoproteocephalidea
Classification

Trypanorhyncha

Rhinebothriidea

Lecanicephalidea

Onchopreoteocephalidea

New suborders:
- Trypanobatoidea
- Trypanoselaoidea

New families:
- Anthocephaliidae
- Escherbothriidae

New family-level classification

New families:
- Aberrapecidae
- Eniochobothriidae
- Paraberrapecidae
- Zanobatocestidae

New family:
- Rhoptrobothriidae

New family:
- Testudotaeniinae
Dissemination
Dissemination
Dissemination

LIST OF ILLUSTRATIONS
- apical organ
- apical organ (invaginated)
- body regions
- bothridial hooks
- bothridium
- bothrium
- cirrus
- cirrus (armed)
- cirrus (evaginated)
- coracidium
- genital pores (separate)
- hermaphroditic sac
- lappet
- lateral diverticula
- loculi
- male ducts
- metascoleces
- microtriches
- monozoic
- nerves
- onchosphere
- ootype
- paruterine capsule
- paruterine organ
- pedicel
- proglottid
- proglottid maturity
- proteronephridia
- reproductive organs (1 set)
- reproductive organs (2 sets)
- rostellum apparatus (invaginated)
- rostellar apparatus (retractile)
- rostellum
- rostellar apparatus (retracted)
- scolex (monobothriate)
- stalk
- scolex
Dissemination
Global Cestode Database

# of records: 12,274
# of valid genera: 592
# of valid species: 3,143
Dissemination
Dissemination

# of citations: 3,887
Dissemination
Dissemination
Outreach

University of Kansas, Natural History Museum
MEET THE SUCKERS

A book about tapeworms by Lenta Chervy
Go on, try them on and explore the world of tapeworms. With these Goggles you can look inside animals.

Really?! We can see INTO animals with these Goggles? Let’s try them at the Aquarium.

Oh, wow! I see one in our goldfish.

Cyri, the spokesworm, arrives with Worm Wear Goggles for Briar and Jacob and opens up for them a whole new exciting world that had been hidden to them until now.
At the Aquarium, with Cyri and their Worm Waer Goggles, the kids begin to see that most animals have tapeworms that live inside of them. Different kinds of tapeworms,....
In the marine mammal exhibit, Briar and Jacob see their second baby tapeworm and learn that hosts get their tapeworms from food, such as raw fish. They see one of the biggest tapeworms there inside of a killer whale. They also see that animals that live in ice, like polar bears, can have tapeworms.
In the shark and stingray tanks, Briar and Jacob see all sorts of beautiful tapeworms. Some sharks and stingrays even host more than one kind of tapeworm.

They see that each type of tapeworm attaches to the gut in its own unique way. Living in a scallop on the floor of the tank they also see their first baby tapeworm.
Bird tapeworms are adorable. Cyri, what do birds eat to get their tapeworms?

These birds eat little shrimp, snails, and beetles, Jacob.

And, at least some must eat dragonflies!

It turns out that all sorts of birds also host tapeworms—wading birds, ducks, flamingos, woodpeckers, and even hummingbirds.

Many of the tapeworms of birds are funny little creatures. The tapeworms of wading birds are so small that as babies they live in dragonflies.
Thanks, Cyri! We had no idea there was so much to see INSIDE the Aquarium.

Cyri, what about a trip to a farm next, with our Worm Wear Goggles?

Sure, I have cousins there, too. But another time. Tonight your neighbor is “hosting” me for dinner.

Next time... can I have Goggles, too?

Watch out for the next adventure of Briar and Jacob and their spokesworm Cyri when they “meet the suckers” of farm animals.


