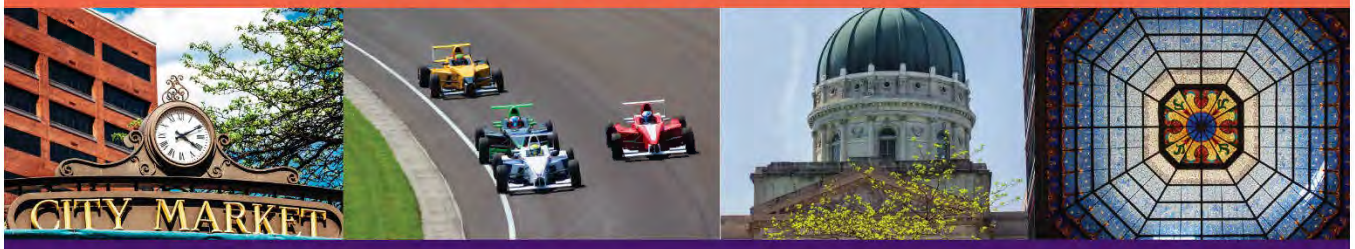
# VETERINARY PARASITOLOGY: THE CLIMATE IS CHANGING




AAVP

## 62nd Annual Meeting Proceedings

July 22 – 25, 2017 • Indianapolis, IN

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Bayer HealthCare Animal Health
bio-techne Diagnostics Division
Boehringer Ingelheim
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Elanco
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MERCK Animal Health
zoetis

# 2017 AAVP-Boehringer Ingelheim Distinguished Veterinary Parasitologist

## Susan E. Little, DVM, PhD, DACVM-Parasit

Susan Little was born in Fort Bragg, North Carolina, the youngest of three children of Nancy and John Little. Her mother was a public librarian and her father was career military, serving in Korea, Vietnam, and as a military advisor in Central America. Much to her delight, the family settled in rural Kentucky where Susan quickly discovered a love of all things animal and, at the age of 5, decided to become a veterinarian.

For undergraduate she attended Cornell University (1985-1989), first majoring in Animal Science. After a year of disillusionment she changed to English and Philosophy and tried to set her veterinary plans aside, but financial need led her to a job washing dishes in a molecular biology lab led by Dr. Carl Batt, now the Liberty Hyde Bailey Professor. As her duties progressed to running sequencing gels and performing protein assays, Susan's fascination with science was rekindled and she changed majors again, graduating with a Biology degree, particularly enjoying comparative zoology in courses like animal behavior, vertebrate anatomy, and wildlife biology.

During her time in Ithaca, Susan also met and fell in love with Rod Will, a fellow biology major embarking on a career in forestry. After graduation they moved to Virginia Tech – Susan for the veterinary medical program and Rod for a master's degree in forestry. Both were completely taken with the natural beauty of the mountains of southwestern Virginia and the vibrant sense of community, and in 1991, they married at Mountain Lake, Virginia.

While at Virginia Tech (1989-1993), the most formative moment of Susan's academic career occurred when she took veterinary parasitology from Dr. Anne Zajac. After just two lectures and completely smitten by the captivating stories of parasites, biology, and health deftly woven by Anne, she asked for a job in

Anne's lab. She began working in both diagnostic parasitology and in research, assisting on pasture pickings, keying out trichostrongyle larvae, and performing glucose tolerance tests related to *Giardia* pathogenesis studies. Focused now on a career in parasitology research, preferably at the wildlife-domestic animal interface, she completed fourth-year rotations at the Southeastern Cooperative Wildlife Disease Study (SCWDS), the National Wildlife Health Laboratory, and with parasitologists and wildlife disease experts at the University of Florida.

Susan and Rod moved to Athens in 1993 where she began a PhD in veterinary parasitology while performing diagnostic work as a wildlife veterinarian at SCWDS and he started on his PhD in forest biology. Susan completed a PhD on sarcoptic mange in red fox under the guidance of Dr. Vic Nettles, then director of SCWDS, and joined the faculty at University of Georgia teaching parasitology to veterinary students and conducting research on vector-borne infections, filling the position left open by the retirement of her teaching mentor, Dr. Ed Roberson. Other key parasitology colleagues at UGA included Drs. Randy Davidson, John McCall, and Michael Yabsley, as well as Ms. Dana Ambrose.

While on faculty at UGA (1996-2005) Susan developed her vector-borne disease program, collaborating with others on human ehrlichiosis research, leading efforts to understand novel tick-borne disease systems, and performing heartworm studies. She received numerous awards including the Norden Distinguished Teacher Award, the Bowen Award for Excellence in Biomedical Research, the national SAVMA Excellence in Teaching Award (Basic Sciences) twice, and was promoted to Associate Professor with tenure. Rod also excelled in a faculty position at UGA and was promoted and tenured as an Associate Professor in Forest Resources. However, the absolute highlight of their time in Athens was welcoming their two children, Edie and Judd Will, in February of 2002.

In 2005, Susan and Rod were invited to move to Oklahoma State University and enthusiastically accepted. Oklahoma State had an endowed position available to support her growing tick research program, many parasitology enthusiasts on faculty, opportunities in forestry through a new Natural Resource Ecology and Management department, and Stillwater presented an idyllic environment to raise their children. As the Krull-Ewing Professor, Susan followed in the path first forged by Drs. Wendell Krull and Sidney Ewing, both of whom dedicated their careers to teaching and to parasitology research. She remains active in teaching parasitology to veterinary and graduate students while overseeing a research program that focuses on zoonotic parasites and vector-borne diseases and includes studies into tick biology, epidemiology of tick-borne infections, diagnosis of parasites and vector-borne infections, and strategies to control parasites in companion animals.

At Oklahoma State (2005-present) she has received class teaching awards numerous times, the Zoetis Award for Research Excellence, and the Zoetis Distinguished Teacher Award. She has authored over 100 publications, presented on parasites around the world, and conducted research with funding support from the National Institutes of Health, the veterinary health industry, and several private foundations. In 2011 she was named Regents Professor, the most prestigious position that may be attained in recognition of scholarly accomplishments by faculty at Oklahoma State. She has served as president of the AAVP and CAPC, a diplomate of the EVPC, and a charter diplomate of the Parasitology subspecialty of the ACVM. As founding director of the National Center for Veterinary Parasitology she led the creation of a new entity to support clinical training and research of veterinary parasitologists throughout North America. Susan's greatest professional joys are working with her close colleagues at Oklahoma State, especially Drs. Kelly Allen, Eileen Johnson, Yoko Nagamori, and Mason Reichard, her colleagues and friends around the world, and her many students, all of whom continue to amaze her with their success.

# AMERICAN ASSOCIATION OF VETERINARY PARASITOLOGISTS AWARDS HISTORY

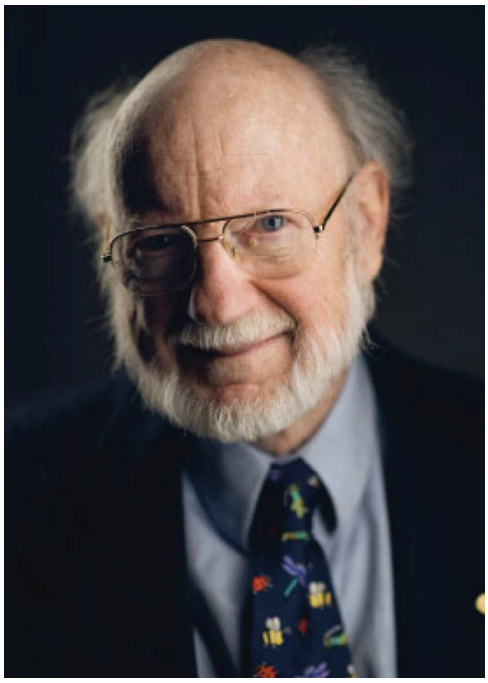
## AAVP-Boehringer Ingelheim Distinguished Veterinary Parasitologist Award

| | |
|---|---|
| 1985 | Jitender P. Dubey[1] |
| 1986 | Norman D. Levine |
| 1987 | E. J. Lawson Soulsby |
| 1988 | Jeffrey F. Williams |
| 1989 | K. Darwin Murrell |
| 1990 | William C. Campbell[2, 3] |
| 1991 | Jay Hal Drudge and Eugene T. Lyons |
| 1992 | Gilbert F. Otto |
| 1993 | Thomas R. Klei |
| 1994 | Peter M. Schantz |
| 1995 | James C. Williams |
| 1996 | T. Bonner Stewart |
| 1997 | J. Owen D. Slocombe |
| 1998 | J. Ralph Lichtenfels |
| 1999 | Roger K. Prichard |
| 2000 | Edward L. Roberson |
| 2001 | Byron L. Blagburn |
| 2002 | Sidney A. Ewing |
| 2003 | Louis C. Gasbarre |
| 2004 | David S. Lindsay |
| 2005 | Jorge Guerrero |
| 2006 | John W. McCall |
| 2007 | Ronald Fayer |
| 2008 | Dwight D. Bowman |
| 2009 | Ellis C. Greiner |
| 2010 | George A. Conder |
| 2011 | Thomas M. Craig |
| 2012 | James E. Miller |
| 2013 | Dante Zarlenga |
| 2014 | Timothy G. Geary |
| 2015 | Michael W. Dryden |
| 2016 | Anne M. Zajac |
| 2017[4] | Susan Little |

[1]National Academy of Sciences 2010
[2]National Academy of Sciences 2002
[3]Noble Prize in Physiology or Medicine, 2015
[4]2017, award renamed the "AAVP-Boehringer Ingelheim Distinguished Veterinary Parasitologist Award"

# 2017 AAVP Distinguished Service Award

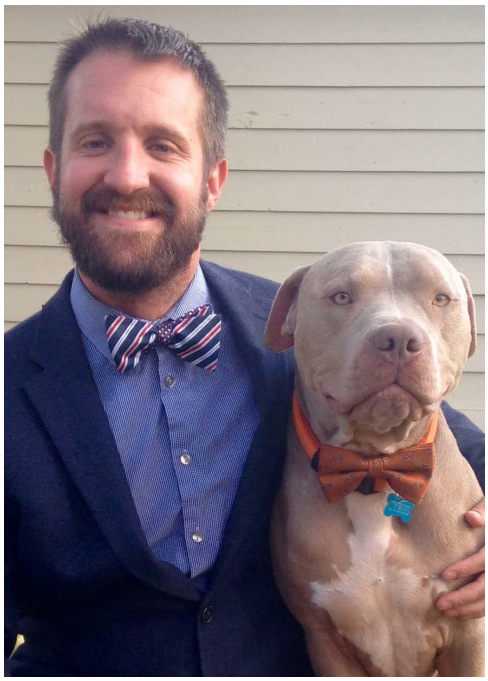
## William C. Campbell



### AAVP Distinguished Service Award

| | |
|---|---|
| **1976** | **Rurel R. Bell** |
| **1983** | **Terance J. Hayes** |
| **1987** | **Norman F. Baker** |
| **1988** | **Donald E. Cooperrider** |
| **1994** | **S. D. "Bud" Folz** |
| **1997** | **Honorico Rick Ciordia** |
| **2006** | **Raffaele "Raf" Roncalli** |
| **2008** | **Anne M. Zajac** |

# 2017 AAVP/Merck Animal Health Graduate Student Research Award
# Brian Herrin



## AAVP/Merck Animal Health Graduate Student Research Award

| | |
|---|---|
| 1987 | Lora G. Rickard |
| 1988 | Debra A. Cross |
| 1989 | Stephen C. Barr |
| 1990 | Jim C. Parsons |
| 1991 | Carlos E. Lanusse |
| 1992 | David G. Baker |
| 1993 | Rebecca A. Cole |
| 1994 | Ray M. Kaplan |
| 1995 | Scott T. Storandt |
| 1996 | A. Lee Willingham III |
| 1997 | Carla C. Siefker |
| 1998 | Ryan M. O'Handley |
| 1999 | John S. Mathew |
| 2000[1] | Sheila Abner |
| 2001 | Andrew Cheadle |
| 2002 | No recipient |
| 2003 | Mary G. Rossano |
| 2004 | Andrea S. Varela |
| 2005 | Alexa C. Rosypal |
| 2006 | Sheila M. Mitchell |
| 2007 | Martin K. Nielsen |
| 2008[2] | Heather D. Stockdale |
| 2009 | Kelly E. Allen |
| 2010 | Stephanie R. Heise |
| 2011 | Aaron S. Lucas |
| 2012[3] | Flavia A. Girao Ferrari |
| 2013 | Lindsay A. Starkey |
| 2014 | Alice Che Yu Lee |
| 2015 | Anne Barrett |
| 2016 | Rachel Curtis-Robles |

[1]2000, award renamed the "AAVP/Intervet Graduate Student Research Award"
[2]2008, award renamed the "AAVP/Schering-Intervet Graduate Student Research Award"
[3]2012, award renamed the "AAVP/Merck Animal Health Graduate Student Research Award"

# 2017 AAVP-CAPC Graduate Student Award in Zoonotic Disease
# Sarah Sapp

## AAVP-Companion Animal Parasite Council (CAPC)
## Graduate Student Award in Zoonotic Disease

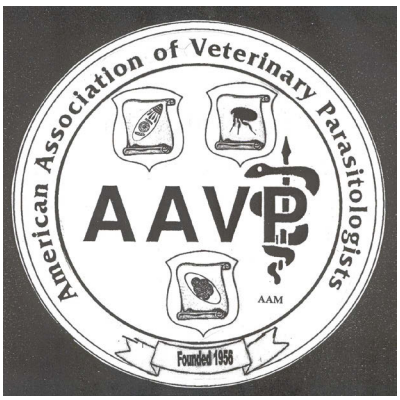
| | |
|---|---|
| **2008** | **David G. Goodman** |
| **2009** | **Stephanie R. Heise** |
| **2010** | **Sriveny Dangoudoubiyam** |
| **2011** | **Jessica Edwards** |
| **2012** | **Lindsay Starkey** |
| **2013** | **Gail M. Moraru** |
| **2014** | **Anne Barrett** |
| **2015** | **Alice Che Yu Lee** |
| **2016** | **Brian H. Herrin** |

# AMERICAN ASSOCIATION OF VETERINARY PARASITOLOGISTS

Founded 1956

## Officers 2016-2017

| | |
|---|---|
| **President** | **Timothy G. Geary**<br>**McGill University**<br>**Montreal, QC, Canada** |
| **President-Elect** | **Dante Zarlenga**<br>**USDA, ARS, APDL**<br>**Beltsville, MD** |
| **Vice-President** | **John S. Gilleard**<br>**University of Calgary**<br>**Calgary, AB, Canada** |
| **Secretary/Treasurer** | **Doug Carithers**<br>**Boehringer Ingelheim**<br>**Duluth, GA** |
| **Immediate Past-President** | **Ray M. Kaplan**<br>**University of Georgia**<br>**Athens, GA** |



# 2016-2017 AAVP Committee Chairs and Members (Term Date)

**Nominations: Ann Donoghue, Chair** (2017), Mason Reichard (2017), Michael Dryden (2018), Alexa Rosypal (2018), Shiela Mitchell (2019), Tom Nolan (2019)

**Archives: Tom Nolan, Chair** (2018), Raf Roncalli (2018), Miguel Suderman (2018), Ann Donoghue (2019)

**Awards: Lindsay Starkey, Chair** (2018), Dante Zarlenga (2017), Alice Lee (2018), Raj Gaji (2018), Gui Verocai (2018), Jim Miller (2018), Joe Camp (2018), Darwin Murrell (2018), Roger Prichard (2018), Jesica Jacobs (2019), Lora Ballweber (2019)

**Constitution and Bylaws: Adrian Wolstenholme, Chair** (2017), Alexa Rosypal (2018), Joe Camp (2018), Andy DeRosa (2019), Ryan Avery (2019)

**Education: Antoinette Marsh, Chair** (2017), Tom Nolan (2017), Andrea Varela-Stokes (2018), Anne Zajac (2017), Andy Moorhead (2017), Araceli Lucio-Forster (2018), Javier Garza (2018), Michael Kent (2018), Lora Ballweber (2018), Ashley McGrew (2018), Joyce Login (2018), Heather Walden (20180, Brian Herrin (2018), Akinsanya Bamidele (2019), Harld Newcomb (2019)

**Electronic Media: Meriam Saleh, Chair** (2019), Alice Houk-Miles (2018), Ann Donoghue (2018), Lauren Lewis (2018), Marie Varloud (2019), Denise Kobuszewski (2019), Brynnan Russ (2019), Denzel Middleton (2019)

**Finance: Andrew Moorhead, Chair** (2017), Jim Miller (2018), Bob Storey (2019), Ashley McGrew (2018), Pete Hann (2018)

**Historian/History: Alan Marchiondo, Chair** (2018), Raf Roncalli (2018), Tom Nolan (2018), Sue Howell (2018), Ashley McGrew (2018)

**Newsletter/Editorial Board: Frank Hurtig, Chair** (2018), Tom Kennedy (2017), Michael Dryden (2017), Lindsay Porter (2018), Brian Herrin (2018), Pablo Jimenez (2018), Miguel Suderman (2018), Kate Purple (2018), Brad Scandrett (2019), Jeba Jesudoss (2019)

**Program: Dante Zarlenga, Chair** (2019), Tim Geary (2018), Ray Kaplan (2017), **Alan Marchiondo, Program Administrator** (2018), Doug Carithers (2018), Jesica Jacobs (2017), Jessica Rodriguez (2018)

**Publications/Outreach/Research: Andy DeRosa, Chair** (2018), Sheila Mitchell (2018), Miguel Suderman (2018), Carly Barone (2018), Chanel Schwartzentruber (2018), Cassan Pulaski (2018), Saurabh Verma (2019), Guilherme Klafke (2019)

**Student Representaives:** Jesica Jacobs (2017), Jessica Rodriguez (2018)

**Past Presidents: Ray Kaplan, Chair** (2019), Andrew Peregrine (2018), Dwight Bowman (2017)

**Ad Hoc List Serve Manager: Bert Stromberg** (2017)

# PAST PRESIDENTS OF THE AMERICAN ASSOCIATION OF VETERINARY PARASITOLOGISTS

| | |
|---|---|
| 1956-1958 | L. E. Swanson |
| 1958-1960 | Fleetwood R. Koutz |
| 1960-1962 | Wendell H. Krull |
| 1962-1964 | Saeed M. Gaafar |
| 1964-1966 | E. D. Besch |
| 1966-1968 | George C. Shelton |
| 1968-1970 | John H. Greve |
| 1970-1972 | Harold J. Griffiths |
| 1972-1973 | Donald E. Cooperrider |
| 1973-1975 | Demetrice L. Lyles |
| 1975-1977 | Harold J. Smith |
| 1977-1979 | Norman F. Baker |
| 1979-1981 | Edward L. Roberson |
| 1981-1983 | Jeffrey F. Williams |
| 1983-1985 | John B. Malone |
| 1985-1986 | Robert M. Corwin |
| 1986-1987 | K. Darwin Murrell |
| 1987-1988 | Thomas R. Klei |
| 1988-1989 | Harold C. Gibbs |
| 1989-1990 | Bert E. Stromberg |
| 1990-1991 | Roger K. Prichard |
| 1991-1992 | J. Owen D. Slocombe |
| 1992-1993 | Ronald Fayer |
| 1993-1994 | George A. Conder |
| 1994-1995 | Charles H. Courtney |
| 1995-1996 | Byron L. Blagburn |
| 1996-1997 | Peter M. Schantz |
| 1997-1998 | James C. Williams |
| 1998-1999 | Louis C. Gasbarre |
| 1999-2000 | Robert S. Rew |
| 2000-2001 | Thomas J. Kennedy |
| 2001-2002 | Anne M. Zajac |
| 2002-2003 | Joseph F. Urban, Jr. |
| 2003-2004 | Craig R. Reinemeyer |
| 2004-2005 | Linda S. Mansfield |
| 2005-2006 | Ann R. Donoghue |
| 2006-2007 | Daniel E. Snyder |
| 2007-2008 | David S. Lindsay |
| 2008-2009 | Susan E. Little |
| 2009-2010 | Lora R. Ballweber |
| 2010-2011 | Karen Snowden |
| 2011-2012 | Patrick F.M. Meeus |
| 2012-2013 | Alan A. Marchiondo |
| 2013-2014 | Dwight D. Bowman |
| 2014-2015 | Andrew S. Peregrine |
| 2015-2016 | Ray M. Kaplan |
| 2016-2017 | Timothy G. Geary |

# PAST SECRETARY-TREASURERS OF THE AMERICAN ASSOCIATION OF VETERINARY PARASITOLOGISTS

| | |
|---|---|
| Wendell H. Krull | 1956-1959 |
| Edward G. Batte | 1960 |
| Donald E. Cooperrider | 1961-1969 |
| Rurel Roger Bell | 1969-1977 |
| Terence J. Hayes | 1978-1983 |
| Vassilios J. Theodorides | 1983-1986 |
| S.D. "Bud" Folz | 1987-1992 |
| Thomas J. Kennedy | 1993-1998 |
| Daniel E. Snyder | 1998-2004 |
| Alan A. Marchiondo | 2004-2010 |
| Robert G. Arther | 2010-2014 |
| Doug Carithers | 2014- Present |

# PAST AAVP ANNUAL MEETINGS

| | | |
|---|---|---|
| 1956 | 1st Annual Meeting – SAN ANTONIO, TX | 16 OCT |
| 1957 | 2nd Annual Meeting – COLUMBUS, OH | 17 AUG |
| 1958 | 3rd Annual Meeting – PHILADELPHIA, PA | 18 AUG |
| 1959 | 4th Annual Meeting – KANSAS CITY, MO | 23 AUG |
| 1960 | 5th Annual Meeting – DENVER, CO | 14 AUG |
| 1961 | 6th Annual Meeting – WEST LAFAYETTE, IN | 20 AUG |
| 1962 | 7th Annual Meeting – MIAMI BEACH, FL | 12 AUG |
| 1963 | 8th Annual Meeting – NEW YORK CITY, NY | 28 JUL |
| 1964 | 9th Annual Meeting – CHICAGO, IL | 19 JUL |
| 1965 | 10th Annual Meeting – PORTLAND, OR | 11 JUL |
| 1966 | 11th Annual Meeting – LOUISVILLE, KY | 13 JUL |
| 1967 | 12th Annual Meeting – DALLAS, TX | 9 JUL |
| 1968 | 13th Annual Meeting – BOSTON, MA | 21 JUL |
| 1969 | 14th Annual Meeting – MINNEAPOLIS, MN | 13 JUL |
| 1970 | 15th Annual Meeting – LAS VEGAS, NV | 22 JUN |
| 1971 | 16th Annual Meeting – DETROIT, MI | 18 JUL |
| 1972 | 17th Annual Meeting – NEW ORLEANS, LA | 17 JUL |
| 1973 | 18th Annual Meeting – PHILADELPHIA, PA | 15 JUL |
| 1974 | 19th Annual Meeting – DENVER, CO | 21 JUL |
| 1975 | 20th Annual Meeting – ANAHEIM, CA | 13 JUL |
| 1976 | 21st Annual Meeting – CINCINNATI, OH | 19 JUL |
| 1977 | 22nd Annual Meeting – ATLANTA, GA | 11 JUL |
| 1978 | 23rd Annual Meeting – DALLAS, TX | 17 JUL |
| 1979 | 24th Annual Meeting – SEATTLE, WA | 22-24 JUL |
| 1980 | 25th Annual Meeting – WASHINGTON, D.C. | 20-22 JUL |
| 1981 | 26th Annual Meeting – ST. LOUIS, MO | 19-20 JUL |
| 1982 | 27th Annual Meeting – SALT LAKE CITY, UT | 18-19 JUL |
| 1983 | 28th Annual Meeting – NEW YORK, NY | 17-18, JUL |
| 1984 | 29th Annual Meeting – NEW ORLEANS, LA | 15-17 JUL |
| 1985 | 30th Annual Meeting – LAS VEGAS, NV | 22-24 JUL |
| 1986 | 31st Annual Meeting – ATLANTA, GA | 20-22 JUL |
| 1987 | 32nd Annual Meeting – CHICAGO, IL | 19-21 JUL |

| | | |
|---|---|---|
| 1988 | 33rd Annual Meeting – PORTLAND, OR | 17-18 JUL |
| 1989 | 34th Annual Meeting – ORLANDO, FL | 16-18 JUL |
| 1990 | 35th Annual Meeting – SAN ANTONIO, TX | 21-24 JUL |
| 1991 | 36th Annual Meeting – SEATTLE, WA | 28-30 JUL |
| 1992 | 37th Annual Meeting – BOSTON, MA | 2 - 4 AUG |
| 1993 | 38th Annual Meeting – MINNEAPOLIS, MN | 17-20 JUL |
| 1994 | 39th Annual Meeting – SAN FRANCISCO, CA | 9-12 JUL |
| 1995 | 40th Annual Meeting – PITTSBURGH, PA | 6-10 JUL |
| | *(Joint meeting with the American Society of Parasitologists)* | |
| 1996 | 41st Annual Meeting – LOUISVILLE, KY | 20-23 JUL |
| 1997 | 42nd Annual Meeting – RENO, NV | 19-22 JUL |
| 1998 | 43rd Annual Meeting – BALTIMORE, MD | 25-28 JUL |
| 1999 | 44th Annual Meeting – NEW ORLEANS, LA | 10-13 JUL |
| 2000 | 45th Annual Meeting – SALT LAKE CITY, UT | 22-25 JUL |
| 2001 | 46th Annual Meeting – BOSTON, MA | 14-17 JUL |
| 2002 | 47th Annual Meeting – NASHVILLE, TN | 13-16 JUL |
| 2003 | 48th Annual Meeting – DENVER, CO | 19-23 JUL |
| 2004 | 49th Annual Meeting – PHILADELPHIA, PA | 24-28 JUL |
| | *(Joint meeting with the American Society of Parasitologists)* | |
| 2005 | 50th Annual Meeting – MINNEAPOLIS, MN | 16-19 JUL |
| 2006 | 51st Annual Meeting – HONOLULU, HI | 15-18 JUL |
| 2007 | 52ndAnnual Meeting – WASHINGTON, DC | 14-17 JUL |
| 2008 | 53rd Annual Meeting – NEW ORLEANS, LA | 19-22 JUL |
| 2009 | 54th Annual Meeting – CALGARY, CANADA | 9-13 AUG |
| | *(Joint meeting with the World Association for the Advancement of Veterinary Parasitology and the International Commission on Trichinellosis)* | |
| 2010 | 55th Annual Meeting – ATLANTA, GA | 31 JUL – 2 AUG |
| 2011 | 56th Annual Meeting – ST. LOUIS, MO | 16-19 JUL |
| | *(Joint meeting with the Livestock Insect Workers Conference and the International Symposium of Ectoparasites of Pets)* | |
| 2012 | 57th Annual Meeting – San Diego, CA | 4-7 AUG |
| 2013 | 58th Annual Meeting – Chicago, IL | 20-23 JUL |
| 2014 | 59th Annual Meeting – Denver, CO | 26-29 JUL |
| 2015 | 60th Annual Meeting – Boston, MA | 11-14 JUL |
| | *(Joint meeting with the Livestock Insect Workers Conference and the International Symposium of Ectoparasites of Pets)* | |
| 2016 | 61st Annual Meeting – San Antonio, TX | 6-9 AUG |

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# AAVP 62nd ANNUAL MEETING
# Sheraton Indianapolis City Centre Hotel

REGISTRATION
Meridian (Lower) Foyer
Saturday, July 22, 2017, 1:00 PM – 5:00 PM
Sunday, July 23, 2017, 8:00 AM – 6:00 PM
Monday, July 24, 2017, 8:00 AM – 12:00 PM

## SYMPOSIA / SOCIAL PROGRAMS

## Welcoming Reception – Bayer HealthCare, Animal Health
Bayer Social - Panorama Ballroom – Saturday, July 22, 2017, 7:00 PM – 9:00 PM

## AAVP Committee-Volunteers Breakfast
## (Breakfast only for those volunteering for/on AAVP Committees)
**Breakfast Meeting Sponsored by AAVP**
Panorama Ballroom – Sunday, July 23, 2017, Breakfast 7:00 AM – 7:30 AM,
Committee Meetings 7:30 AM – 8:30 AM

## Zoetis Lunch Symposium
Zoetis Lunch Symposium - Meridian West and Center - Sunday, July 23, 2017,
12:00 PM – 1:00 PM

## Poster Viewing and Wine Social
**Social Sponsored by CEVA Animal Health**
Monument Suite & Meridian (Lower) Foyer - Sunday, July 23, 2017, 5:00 PM – 6:15 PM

## Boehringer Ingelheim Seminar / Social
Boehringer Ingelheim Seminar - Meridian West-Center - Sunday, July 23, 2017,
6:30 PM – 7:30 PM
Boehringer Ingelheim Social - Panorama Ballroom - Sunday, July 23, 2017,
7:30 PM – 9:30 PM

## Bio-Techne Lunch Seminar
Bio-Techne Lunch Seminar - Meridian West and Center - Monday, July 24, 2017,
12:15 PM – 1:30 PM

## Poster Viewing and Wine Social
## Social Sponsored by CEVA Animal Health

Monument Suite & Meridian (Lower) Foyer - Monday, July 24, 2017, 5:00 PM – 6:15 PM

## DACVM Meeting

Meridian East– Monday, July 24, 2017, 5:30 PM – 6:30 PM

## Elanco Animal Health Social

Elanco Social
Eli Lilly and Co. Headquarters
Delaware and McCarty Streets
Monday, July 24, 2017, 7:00 PM – 9:00 PM

## AAVP- National Center for Veterinary Parasitology (NCVP)
## Parasite Case Discussions

**Boxed Lunches Sponsored by NCVP**

Meridian East – Tuesday, July 25, 2017, 10:30 AM – 12:30 PM

## COFFEE BREAKS

Meridian (Lower) Foyer, Saturday, July 22, 2017, 4:30 PM – 5:15 PM
Meridian (Lower) Foyer, Sunday, July 23, 2017, 10:00 AM – 10:30 AM
Meridian (Lower) Foyer, Sunday, July 23, 2017, 3:00 PM – 3:30 PM
Meridian (Lower) Foyer, Monday, July 24, 2017, 10:00 AM – 10:30 AM
Meridian (Lower) Foyer, Monday, July 24, 2017, 3:00 PM – 3:30 PM

# STUDENT FUNCTIONS

## AAVP Student Member Meet and Greet

Lunch Sponsored by Virbac

**Circle Center and East - Saturday, July 22, 2017, 12:00 – 1:00 PM**

## AAVP Students – Lunch: Careers in Parasitology

Lunch Sponsored by Virbac

**Circle Center and East** - Sunday, July 23, 2017, Noon – 1:30 PM

## AAVP Students - Lunch and AAVP Student Elections

Lunch Sponsored by Virbac

**Circle Center and East** - Monday, July 24, 2017, Noon – 1:30 PM

## AAVP Students – Elanco-Indianapolis Zoo Tour

Tuesday, July 25, 2017, 1:00 PM

Students attending the tour of the Indianapolis Zoo should meet in the lobby of the Sheraton Indianapolis City Centre hotel by 1:00 p.m. on Tuesday, July 25. After visiting the zoo, Elanco will provide dinner in downtown Indianapolis. Hotel rooms will be provided by the AAVP on Tuesday night at the Comfort Inn at the Indianapolis airport.

# AMERICAN ASSOCIATION OF VETERINARY PARASITOLOGISTS 62nd ANNUAL MEETING SPONSORS

## SOCIAL EVENT SPONSORS

AAVP
BAYER HEALTHCARE, ANIMAL HEALTH
BOEHRINGER INGELHEIM*
BIO-TECHNE (Diagnostic Division)
CEVA ANIMAL HEALTH
ELANCO ANIMAL HEALTH
NATIONAL CENTER FOR VETERINARY PARASITOLOGY
ZOETIS**
*Plus In-Kind Annual Support of the AAVP Secretary/Treasurer
**Plus In-Kind support for the Proceedings Covers, Meeting App Design, Student Certificates and Name Badges

## AWARDS SPONSORS

BAYER HEALTHCARE, ANIMAL HEALTH[1]
BOEHRINGER INGELHEIM [2]
COMPANION ANIMAL PARASITE COUNCIL[3]
ELANCO ANIMAL HEALTH[4]
MERCK ANIMAL HEALTH[5]
[1]AAVP- Bayer Best Student Oral Presentation Awards
[2] AAVP-Boehringer Ingelheim Distinguished Veterinary Parasitologist Award
[3] AAVP-CAPC Graduate Student Award – Zoonotic Diseases
[4] AAVP-Elanco Best Student Poster Presentation Awards
[5]AAVP-Merck Animal Health Graduate Student Award – Research

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# GENERAL MEETING SPONSORSHIP (cont)

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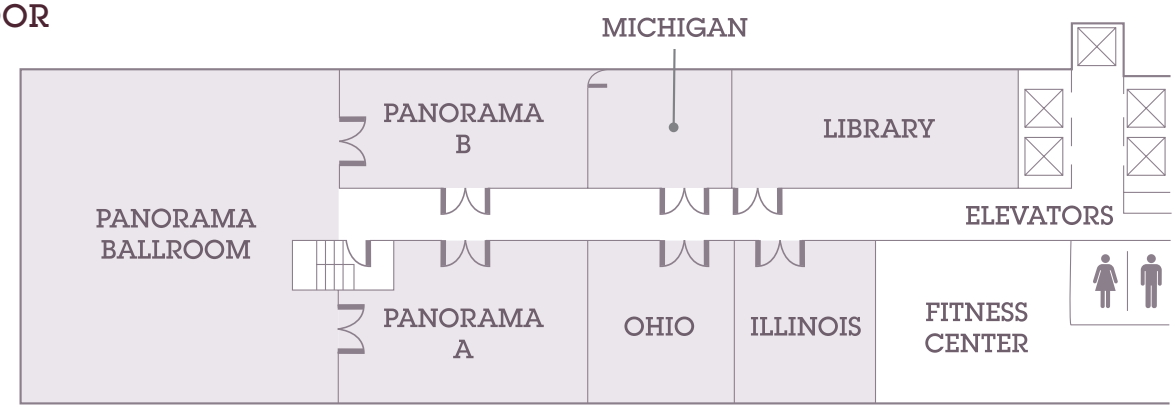
# NOTES

# NOTES

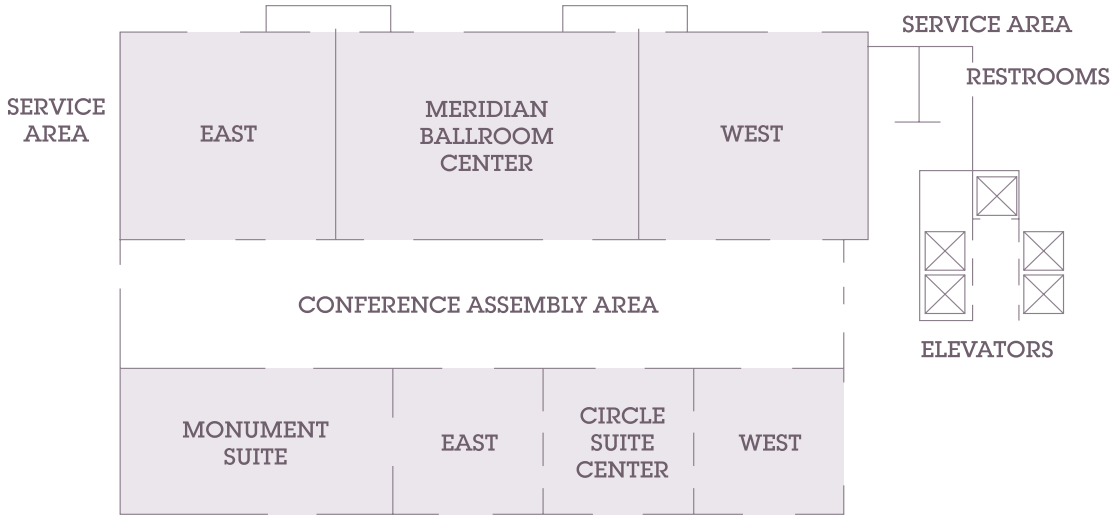
# NOTES

# Sheraton Indianapolis City Centre Floor Plan

## 21ST FLOOR




## LOWER LEVEL



# 2017 AAVP PROGRAM
## ORAL PRESENTATIONS

| CONFERENCE PROGRAM | |
|---|---|
| Saturday July 22, 2017 | |
| 8.00-13.15 | **AAVP Executive Committee Meeting**<br>*All AAVP officers and committee chairs please plan to attend*<br>Room: **Panorama Ballroom (21st floor)** |
| 12.00-13.00 | **AAVP Student Member Meet and Greet – All Students Please Attend**<br>**Sponsored by Virbac**<br>Room: **Circle Center and East** |
| 13.00-17.00 | **CONFERENCE REGISTRATION**<br>Room: **Meridian (Lower) Foyer** |
| 13.15-14.00 | **Break** (no refreshments) |
| 14.00-16.30 | **PLENARY SESSION: Veterinary Parasitology: The Climate Is Changing**<br>Room: **Meridian West & Center** |
| 14.00-14.15 | **Opening remarks**<br>AAVP President: **Timothy G. Geary**<br>AAVP President-Elect and Program Chair: **Dante Zarlenga** |
| 14.15-16.30 | **PLENARY SESSION**<br>Moderator: **Dante Zarlenga**<br>1. A crucible of accelerating climate change<br>**Eric Hoberg**<br>*Animal Parasitic Disease Laboratorry, ARS, USDA*<br>2. Within-host processes shape host heterogeneity and the impact of climate changes on parasitic infections<br>**Isabella Cattadori**<br>*Penn State University*<br>**2017 AAVP Distinguished Service Award**<br>**William C. Campbell**<br>*2015 Nobel Prize winner in Physiology or Medicine* |
| 16.30-17.15 | **Coffee Break** (**Lower (Meridian) Foyer**) |
| 17.15-18.30 | **AAVP AWARDS**<br>Room: **Meridian West & Center** |
| 17.15-17.45 | **2017 AAVP-Merck Animal Health Outstanding Graduate Student**<br>Moderator: Lindsay Starkey<br>3. Geographic distribution of Lyme borreliosis in North America<br>*Awarded to **Brian Herrin*** |
| 17.45-18.30 | **2017 AAVP-Boehringer Ingelheim Distinguished Veterinary Parasitologist**<br>Moderator: Doug Carithers<br>*Awarded to **Susan Little*** |
| 18.30-19.00 | **Break** (no refreshments) |
| 19.00-21.00 | **Bayer Opening Night Social**<br>Room: **Panorama Ballroom** |

| Sunday July 23, 2017 | | |
|---|---|---|
| 7.00-8.30 | **AAVP Committee Meetings**<br>**(Breakfast only for those volunteering for/on committees - Sponsored by AAVP)**<br>**Breakfast: 7:00-7:30 / Committee Meetings: 7:30-8:30**<br>Room: **Panorama Ballroom (21st floor)** | |
| 8.30-11.45 | **CONCURRENT SCIENTIFIC SESSIONS** | |
| 8.30-10.00 | **Session 1: Drug Resistance:Nematodes**<br>Room: **Meridian West and Center**<br>Moderators: T. Geary, M. George | **Session 2: Immunology**<br>Room: **Meridian East**<br>Moderators: J. Jacobs, W. Tuo |
| 8.30-8.45 | 4. Evaluation of in vitro microfilarial motility to reflect the resistance status of *Dirofilaria immitis* isolates to macrocyclic lactones<br>**Adrian Wolstenholme**<br>*University of Georgia* | 10. Ovine-derived neutrophils preferentially form NETs in response to different life stages of *Haemonchus contortus* in vitro.<br>**Javier Garza**<br>*West Virginia University* |
| 8.45-9.00 | 5. Using population genetics to explore the origins of macrocyclic lactone resistance in *Dirofilaria immitis*<br>**Julie Sanchez**<br>*University of Calgary* | 11. Effects of ovine monocytes on *Haemonchus contortus* larvae in vitro reveal alternative activation state.<br>**Elizabeth Shepherd**<br>*West Virginia University* |
| 9.00-9.15 | 6. *Dirofilaria immitis* JYD-34 isolate: whole genome analysis<br>**Roger Prichard**<br>*McGill University* | 12. Ovine neutrophils rapidly produce Interleukin-4 (IL-4) in response to *Haemonchus contortus* larval antigen in vitro<br>**Denzel Middleton**<br>*West Virginia University* |
| 9.15-9.30 | 7. Heartworm preventive drug 'lack of effectiveness' claims submitted to the FDA (2004-2015): an analysis of reports and further application<br>**Cassan Pulaski**<br>*Louisiana State University* | 13. Antigenic epitopes of *Haemonchus contortus* third stage larval cuticle are recognized by antibody derived from parasite-resistant sheep.<br>**Brynnan Russ**<br>*West Virginia University* |
| 9.30-9.45 | 8. Prevalence of gastrointestinal nematode resistance to avermectin anthelmintics on beef cattle operations in Georgia<br>**Kelsey Paras**<br>*University of Georgia* | 14. Histopathologic Evaluation of Local Inflammatory Responses Surrounding Encysted Larval Cyathostomins in 36 Moxidectin and Fenbendazole Treated Ponies<br>**Ashley Steuer**<br>*University of Kentucky* |
| 9.45-10.00 | 9. A 16-year retrospective analysis of anthelmintic resistance on small ruminant farms in the United States.<br>**Sue Howell**<br>*University of Georgia* | 15. Histopathologic changes at the tick-host interface of *Amblyomma americanum* on tick-naïve domestic cats (*Felis catus*)<br>**Jennifer Thomas**<br>*Texas A&M University* |
| 10.00-10.30 | **Coffee Break (Meridian (Lower) Foyer)** | |
| 10.30-11.45 | **Session 3: Parasite Control-1: Drug Therapy**<br>Room: **Meridian West and Center**<br>Moderators: R. Kaplan, S. Irurueta | **Session 4: Molecular and Biochemical-1**<br>Room: **Meridian East**<br>Moderators: A. Wolstenholme, S.Verma |
| 10.30-10.45 | 16. Macrocyclic lactone (ML) anthelmintics lack meaningful in vitro activity against L3 and L4 stages of both ML-susceptible and ML-resistant *Dirofilaria immitis*<br>**Pablo Jimenez Castro**<br>*University of Georgia* | 21. Utilizing next generation sequencing to discover highly repetitive DNA sequence targets for real-time PCR diagnosis of *Heterobilharzia americana*<br>**Jessica Rodriguez**<br>*Texas A&M University* |

| Sunday July 23, 2017 (continued) | | |
|---|---|---|
| 10.45-11.00 | 17. Moxidectin and fenbendazole treatment of equine cyathostomins – adulticidal/larvicidal efficacy, egg reappearance period, and species composition.<br>**Jennifer Bellaw**<br>*University of Kentucky* | 22. Does the benzimidazole drug fenbendazole have multiple targets in nematodes?<br>**Susan Stasiuk**<br>*University of Calgary* |
| 11.00-11.15 | 18. Emodepside: Activation of SLO-1 K currents in *Brugia malayi* and *Xenopus oocyte* expressed channels<br>**Richard Martin**<br>*Iowa State University* | 23. The use of deep amplicon sequencing for wide-scale scanning of ovine parasitic nematode populations for benzimidazole resistance mutations<br>**Camila Queiroz**<br>*University of Calgary* |
| 11.15-11.30 | 19. Selective therapy to control cyathostomins in Thoroughbred mares<br>**Luciana Dias de Castro**<br>*Universidade Federal do Paraná, Brazil* | 24. Single Nucleotide Polymorphisms in immune gene transcripts are associated with T helper type 2 response in St. Croix sheep<br>**Jesica Jacobs**<br>*Emory University* |
| 11.30-11.45 | 20. A one-herd evaluation of internal and external parasite controls on Arkansas stocker cattle.<br>**Eva Wray**<br>*University of Arkansas* | 25. Defining global transcriptomic differences between different strains of *Haemonchus contortus* in the face of high levels of sequence polymorphism<br>**John Gilleard**<br>*University of Calgary* |
| 12.00-13.00 | **Zoetis Lunch Symposium**<br>Moderator: **Tom McTier**<br>Title: **Sarolaner: A Proven, Broad-Spectrum Oral Isoxazoline**<br>Speakers: **Tom McTier, Joyce Login, Chris Adolph, Thomas Guerden, Steve Maeder**<br>Room: **Meridian West and Center** | |
| | **AAVP Students – Lunch and Careers in Parasitology**<br>**Sponsored by Virbac**<br>Room: **Circle Center and East** | |
| 13.30-16.45 | **CONCURRENT SCIENTIFIC SESSIONS** | |
| 13.30-15.00 | **Session 5: Diagnosis-1: Mixed Species**<br>Room: **Meridian West and Center**<br>Moderators: K. Paras, K. Monti | **Session 6: Epidemiology-1: Protozoa**<br>Room: **Meridian East**<br>Moderators: Y. Nagamori, S. Ammar |
| 13.30-13.45 | 26. Advancements in marine parasitology: optimization of diagnostic techniques and development of educational tools<br>**Jacob Rodgers**<br>*Colorado State University* | 32. *Encephalitozoon cuniculi* survey in a dog breeding kennel<br>**Karen Snowden**<br>*Texas A&M University* |
| 13.45-14.00 | 27. Evaluation of the card agglutination test (CATT/ *T. evansi*) for detection of *Trypanosoma evansi* infection in donkeys in Egypt.<br>**Mosaad Hilali**<br>*Cairo University* | 33. *Toxoplasma* and *Sarcocystis* spp. cysts found in raw meat-based diets for cats and dogs<br>**Paul A.M. Overgaauw**<br>*Utrecht University* |
| 14.00-14.15 | 28. Serological diagnosis of *Parelaphostrongylus tenuis* Infection<br>**Jessie Richards**<br>*University of Tennessee* | 34. Investigation of the Potential Transmission of *Histomonas meleagridis* from Poultry Litter to Wild Turkeys<br>**Richard Gerhold**<br>*University of Tennessee* |
| 14.15-14.30 | 29. A Niche and Lonely Endeavor: Investigating the cestodes of wild turkeys (*Meleagris gallopavo silvestris*) from Tennessee.<br>**Kathryn Duncan**<br>*University of Georgia* | 35. Serologic detection of *Trypanosoma cruzi* infections in free-roaming feral and stray cats in Oklahoma.<br>**Kelly Allen**<br>*Oklahoma State University* |

| Sunday July 23, 2017 (continued) | | |
|---|---|---|
| 14.30-14.45 | 30. The value of PCR in the diagnosis of canine giardiasis<br>**Meriam Saleh**<br>*Virginia Tech* | 36. Dog kennels as a nidus of infection: triatomine vector activity, *Trypanosoma cruzi* infection dynamics and Chagas disease cardiomyopathy in a central Texas dog kennel<br>**Rachel Curtis-Robles**<br>*Texas A&M University* |
| 14.45-15.00 | 31. Efficacy of the mini-FLOTAC, in the diagnosis of canine *Giardia* infection<br>**Lauren Page**<br>*Virginia Maryland College of Veterinary Medicine* | 37. Infection of *Babesia conradae* in hunting greyhounds from Oklahoma<br>**Mason Reichard**<br>*Oklahoma State University* |
| 15.00-15.30 | **Coffee Break (Meridian (Lower) Foyer)** | |
| 15.30-16.45 | **Session 7: Molecular and Biochemical - 2**<br>Room: **Meridian West and Center**<br>Moderators: J. Gilleard, C. Queiroz | **Session 8: Case Reports and Novel Findings**<br>Room: **Meridian East**<br>Moderators: T. McTier, M. Savadelis |
| 15.30-15.45 | 38. Improved sampling for and determination of seasonal incidence of dog heartworm-infected mosquitoes<br>**Phillip Kaufman**<br>*University of Florida* | 43. Case Report: Uncommon cause of dermatitis in a dog – *Pelodera* (syn. *Rhabditis*) *strongyloides* infestation<br>**Yoko Nagamori**<br>*Oklahoma State University* |
| 15.45-16.00 | 39. Molecular evidence for black flies (*Simulium* spp.) as vectors of an uncharacterized *Onchocerca* species<br>**Guilherme Verocai**<br>*University of Georgia* | 44. Case report: Fatal *Strongyloides stercoralis* infection in a 12-week-old puppy in Oklahoma, USA<br>**Yoko Nagamori**<br>*Oklahoma State University* |
| 16.00-16.15 | 40. Inherent Oxidative Stress in Lewis Rat Mediates Resistance to Toxoplasmosis<br>**William Witola**<br>*University of Illinois at Urbana-Champaign* | 45. Dermal microfilariae of *Cercopithifilaria bainae* in a dog in south Florida: First report in the United States<br>**Heather Walden**<br>*University of Florida* |
| 16.15-16.30 | 41. A unique plant-like nuclear kinase plays an essential role in acute toxoplasmosis<br>**Raj Gaji**<br>*Indiana University* | 46. Associations between fecal egg count, presence of *Strongylus vulgaris*, and body score of feral horses on Fort Polk, Louisiana<br>**Jennifer Cain**<br>*University of Nebraska at Kearney* |
| 16.30-16.45 | 42. Characterization of a ATP binding cassette transporter from *Toxocara canis*<br>**Jeba Jesudoss Chelladurai**<br>*Iowa State University* | 47. Experimental transmission of an *Ehrlichia* spp. following exposure to *Amblyomma americanum*<br>**Brian Herrin**<br>*Oklahoma State University* |
| 17.00-18.15 | **Poster Viewing and Wine Social**<br>**Sponsored by Ceva**<br>Rooms: **Monument Suite & Meridian (Lower) Foyer** | |
| 18.15-18.30 | **Break** (no refreshments) | |
| 18.30-19.30 | **Boerhinger Ingelheim Seminar**<br>Moderator: **Doug Carithers**<br>Title: **A Practical Look at LONGRANGE® (eprinomectin): 3 Years Out**<br>Speaker: **Dr. Tony Moravec**<br>Room: **Meridian West and Center** | |
| 19.30-21.30 | **Boerhinger Ingelheim Sunday Night Social**<br>Room: **Panorama Ballroom** | |

| Monday July 24, 2017 | | |
|---|---|---|
| Prior to 8:30 | **Breakfast on your own** | |
| 8.30-10.00 | **CONCURRENT SCIENTIFIC SESSIONS** | |
| 8.30-10.00 | **Session 9: Parasite Control-2: Natural Approaches**<br>Room: **Meridian West and Center**<br>Moderators: R. Prichard, P.D. Jimenez Castro | **Session 10: Diagnosis-2: Nematodes**<br>Room: **Meridian East**<br>Moderators: S. Howell, M. Saleh |
| 8.30-8.45 | 48. Impact of a refugia-based strategy in stocker cattle on species diversity, pasture contamination, and development of resistance<br>**Ray Kaplan**<br>*University of Georgia* | 54. Comparison of Kato-Katz, mini-FLOTAC, and multi-parallel real-time polymerase chain reaction techniques for detection of soil-transmitted helminths in Feira de Santana, Brazil<br>**Ryan Avery**<br>*Louisiana State University* |
| 8.45-9.00 | 49. Evaluation of a refugia-based strategy in pastured stocker cattle treated with LongRange®<br>**Kelsey Paras**<br>*University of Georgia* | 55. The Propensity of Density: Determining Specific Gravity of Equine Parasite Eggs<br>**Jamie Norris**<br>*University of Kentucky* |
| 9.00-9.15 | 50. Effects of terminal sire breed on parasitism of crossbred market lambs in a hair sheep production system<br>**Andrew Weaver**<br>*Virginia Polytechnic and State University* | 56. Deep amplicon nemabiome sequencing reveals high species diversity and emerging benzimidazole resistance in gastro-intestinal nematode parasites of Canadian bison<br>**John Gilleard**<br>*University of Calgary* |
| 9.15-9.30 | 51. The enemy of my enemy is my friend: using a soil bacterium to kill parasitic nematodes<br>**Hanchen Li**<br>*University of Massachusetts Medical School* | 57. Antibody concentrations against gastrointestinal nematodes in adult beef cows from the prairie provinces of western Canada<br>**Felicity Wills**<br>*University of Saskatchewan* |
| 9.30-9.45 | 52. Evaluation of internal parasite resistance in terminal-sire sheep breeds infected with *Haemonchus contortus*<br>**Scott Bowdridge**<br>*West Virginia University* | 58. Evaluation of a smartphone based automated parasite egg counting system to the McMaster and Wisconsin methods<br>**Jessica Scare**<br>*University of Kentucky* |
| 9.45-10.00 | 53. Capture mechanisms of *Duddingtonia flagrans* on equine cyathostomin larvae<br>**Justin Blair**<br>*University of Delaware* | 59. Utilization of composite fecal samples for detection of anthelmintic resistance in gastrointestinal nematodes of cattle<br>**Melissa George**<br>*University of Georgia* |
| 10.00-10.30 | **Coffee Break (Meridian (Lower) Foyer)** | |
| 10.30-12.00 | **AAVP Business Meeting & Awards**<br>AAVP Executive Committee, Student Officers, Corporate Sponsor representatives, and Awardees stay for pictures<br>Room: **Meridian West and Center** | |
| 12.15-13.30 | **AAVP Students – Lunch and Student Elections**<br>**Sponsored by Virbac**<br>Room: **Circle Center and East** | |
| | **Bio-Techne Lunch Seminar**<br>Title: **Fecal Diagnostic Procedures: Past, Present and Future**<br>Speaker: **Byron Blagburn**<br>Room: **Meridian West and Center** | |

| Monday July 24, 2017 (continued) | | |
|---|---|---|
| 13.30-17.00 | **CONCURRENT SCIENTIFIC SESSIONS** | |
| 13.30-15.00 | **Session 11: Parasite Control-3: Vaccines & Widespread Studies**<br>Room: **Meridian West and Center**<br>Moderators: R. Martin, J. Richards | **Session 12: Epidemiology-2: Nematodes**<br>Room: **Meridian West**<br>Moderators: S. Bowdridge, R. Imai |
| 13.30-13.45 | 60. Safety of a *Haemochus contortus* vaccine (Barbervax) in camelids<br>**Grace VanHoy**<br>*Ohio State University* | 66. Intestinal Nematode Prevalence in Dallas/Fort Worth Public Dog Parks: Free Fun but not Free of Worms<br>**Kristina Stafford**<br>*Elanco Animal Health* |
| 13.45-14.00 | 61. Dose optimisation of a candidate vaccine against *Cryptosporidium parvum* infection<br>**Karine Sonzogni-Desautels**<br>*McGill University* | 67. The prevalence and epidemiologic characteristics of canine *Baylisascaris procyonis* infections in the United States, 2013-2016.<br>**Sarah Sapp**<br>*University of Georgia* |
| 14.00-14.15 | 62. *Eimeria* oocyst cycling patterns in commercial broilers reared in conventional or antibiotic free production.<br>**Ryan Snyder**<br>*University of Guelph* | 68. Equine strongyle egg shedding patterns in the western region of the state of São Paulo, Brazil<br>**Lívia Ramires**<br>*University of Western São Paulo* |
| 14.15-14.30 | 63. Decreased dissolved oxygen as a possible mechanism of increased persistence of *Trichomonas gallinae* in the presence of organic material in water<br>**Kathryn Purple**<br>*University of Tennessee* | 69. Observation of *Strongyloides westeri* burden in naturally infected foals at 4-8 months of age<br>**Faith Miller**<br>*University of Kentucky* |
| 14.30-14.45 | 64. A statistical approach for evaluating the effectiveness of heartworm drugs: what does 100% efficacy really mean?<br>**Ray Kaplan**<br>*University of Georgia* | 70. *Angiostrongylus cantonensis* in wild rats (*Rattus rattus*) and native and non-native terrestrial snails in Florida.<br>**Heather Walden**<br>*University of Florida* |
| 14.45-15.00 | 65. In vitro efficacy of sarolaner against adult mosquitoes (*Aedes aegypti*)<br>**Tom McTier**<br>Zoetis | 71. Gastrointestinal nematode prevalence and species composition in breeding-age heifers on Canadian dairy farms<br>**Haley Scott**<br>*Western College of Veterinary Medicine* |
| 15.00-15.30 | **Coffee Break (Meridian (Lower) Foyer)** | |
| 15.30-16.45 | **Session 13: Innovative Research**<br>Room: **Meridian West and Center**<br>Moderators: G. Verocai, J. Cain | **Session 14: Epidemiology-3: Ticks and Mix**<br>Room: **Meridian East**<br>Moderators: M. Reichard, N. Crilly |
| 15.30-15.45 | 72. Bovine *Babesia* spp. Recovered after Almost Three Decades in Cryostorage and Comparison of Different Donors of Bovine Erythrocytes and Serum<br>**Amer Alhaboubi**<br>*Texas A&M University* | 77. Ticks from pet cats in the United States: species, stages, and patterns of infestation<br>**Susan Little**<br>*Oklahoma State University* |
| 15.45-16.00 | 73. Cryogenic preservation of *Dirofilaria immitis* microfilariae, re-activation and subsequent development in the mosquito and vertebrate hosts<br>**Erich Zinser**<br>*Zoetis* | 78. Morphological identification of ticks and detection of select tickborne pathogens in ticks collected in East Tennessee.<br>**Nathan Crilly**<br>*University of Tennessee* |
| 16.00-16.15 | 74. Retrospective characterization of the *Brugia pahangi* lymphatic infection model in beagles<br>**Michael Dzimianski**<br>*University of Georgia* | 79. Prevalence of internal parasitic infection in free-roaming cats in Oklahoma based on centrifugal fecal flotation<br>**Yoko Nagamori**<br>*Oklahoma State University* |

| Monday July 24, 2017 (continued) | | |
|---|---|---|
| 16.15-16.30 | 75. Pharyngeal pumping in fourth stage larvae of *Haemonchus contortus*<br>**Adrian Wolstenholme**<br>*University of Georgia* | 80. Detection of *Aeromonas salmonicida* in infected salmonid fish and their parasitic copepods<br>**Natassia Ruse**<br>*Oregon State University* |
| 16.30-16.45 | 76. *Pseudocapillaria tomentosa* in zebrafish, a model for nematode intestinal microbiome studies<br>**Michael Kent**<br>*Oregon State University* | 81. Potentially zoonotic and non-zoonotic parasites in domestic dogs in rural, urban and First Nations communities across Ontario, Canada: Preliminary results from 17 study sites.<br>**Rachel Imai**<br>*University of Guelph* |
| 17.00-18.15 | **Poster Viewing and Wine Social**<br>**Sponsored by Ceva**<br>Room: **Monument Suite & Meridian (Lower) Foyer** | |
| 18.00-18.30 | **Break** (no refreshments) | |
| 17.30-18.30 | **DACVM meeting Meridian East** | |
| 19.00-21.00 | **ELANCO Monday Night SOCIAL**<br>Eli Lilly and Co. Headquarters<br>Delaware and McCarty Streets | |

| Tuesday July 25, 2017 | |
|---|---|
| 8.30-10.00 | **PRESIDENT'S SYMPOSIUM: VETERINARY PARASITOLOGY: THE CLIMATE IS CHANGING** |
| 8.30-10.00 | **PRESIDENTS SYMPOSIUM**<br>Moderator: **Dante Zarlenga**<br>**Announcement of Student Winners & Introduction of Speakers**<br>82. Prospects for manipulating the genome of *Strongyloides* spp.: transgenesis via the male and female germlines and the advent of CRISPR/Cas9 gene disruption and editing.<br>**James Lok**<br>*University of Pennsylvania*<br>83. Prioritizing parasite intervention targets using multi-omics computational approaches<br>**Bruce A. Rosa**<br>*Washington University in Saint Louis*<br>*McDonnell Genome Institute*<br>Room: **Meridian West and Center**<br>**Student Award Winners! Please stay afterwards for group photo.** |
| 10.00-10.30 | **Coffee Break (Meridian (Lower) Foyer)** |
| 10.30-12.30 | **AAVP-NCVP Parasite Case Discussions**<br>Moderator: **Dwight D. Bowman**<br>Boxed lunches for attendees (sponsored by NCVP)<br>Room: **Meridian East** |
| 12.30- | Meeting Adjourns – Happy Trails, to You! |
| 13.00 - | **AAVP Students – Elanco-Indianapolis Zoo Tour**<br>Tuesday, July 25, 2017, 1:00 PM<br>Students attending the tour of the Indianapolis Zoo should meet in the lobby of the Sheraton Indianapolis City Centre hotel by 1:00 p.m. on Tuesday, July 25. Afterwards, Elanco will provide dinner in downtown Indianapolis and rooms will be provided at a hotel near the Indianapolis airport. |

# 2017 AAVP PROGRAM
## POSTER PRESENTATIONS

Please put up all posters in the Monument Suite by Sunday morning and leave your poster up until the end of the Monday poster viewing at 6:15 PM. Plan to stand at your poster during the afternoon wine and cheese poster social per the following schedule.

## Posters 84-95 - Monument Suite, Sunday, July 23, 2017, 5:00 PM – 6:15 PM

| Sunday July 23, 2017 | |
|---|---|
| 17.00-18.15 | **Poster Viewing and Wine Social**<br>Sponsored by CEVA Animal Health<br>Monument Suite |
| **84**. Lack of prolonged benefit for a triple combined anthelmintic treatment and rotational grazing on an anthelmintic-resistant *Haemonchus contortus* population from a winter climate.<br>Pratiksha Khanal, *South Dakota State University* | |
| **85.** Comparison of efficacies of topical eprinomectin, extended-release injectable eprinomectin, and a combination of extended-release injectable eprinomectin and fenbendazole in a population of gastrointestinal nematodes of cattle with known resistance to topical eprinomectin. Melissa George, *University of Georgia* | |
| **86.** The effect of monthly broad-spectrum anthelmintics on intestinal parasite egg shedding in dogs.<br>Sandra Irurueta, *Ross University School of Veterinary Medicine* | |
| **87.** Development of a method for in vivo ruminal exsheathment of *Haemonchus contortus* L3 larvae.<br>Katherine Petersson, *University of Rhode Island* | |
| **88.** *Ostertagia ostertagi* infection upregulates CD23 in abomasa and draining lymph nodes in cattle.<br>Wenbin Tuo, *USDA Animal Parasitic Diseases Lab* | |
| **89.** *Ancylostoma caninum* nicotinic receptor, ACR-16, as a potential drug target for new anthelmintics.<br>James Tipton, *Iowa State College of Veterinary Medicine* | |
| **90**. Does a potential endocytic motif in the calcium activated potassium channel SLO-1 of clade III nematodes affect its localization and function? Hester Swan, *University of Georgia* | |
| **91.** A Targeted Gene Knockdown System in *Cryptosporidium parvum.*<br>Chi Yong Kim, *University of Illinois at Urbana-Champaign*, | |
| **92.** Use of *Dirofilaria immitis*-infected and uninfected canine blood to determine mosquito-feeding preference.<br>Lindsay Starkey, *Auburn University* | |
| **93.** Characterization of the effect of tetracycline antibiotics on the endosymbiont *Wolbachia* during canine heartworm treatment. Molly Savadelis, *University of Georgia*, | |
| **94.** Viability of cryopreserved *Dirofilaria immitis* microfilariae<br>Christopher Evans, *University of Georgia* | |
| **95.** Novel mRNA localization technique to visualize drug target expression in *Parascaris equorum.*<br>Jeba Jesudoss Chelladurai, *Iowa State University* | |

# Posters 96-104 – Monument Suite Monday, July 24, 2017, 5:00 PM – 6:15 PM

| Monday July 24, 2017 | |
|---|---|
| 17.00-18.15 | **Poster Viewing and Wine Social**<br>Sponsored by CEVA Animal Health<br>Monument Suite |
| **96.** Insights into the Impact of Spurious Eggs on Nematode Infection Status in Field Dogs: Percent Agreement of Fecal Dx (Hookworm, Ascarid, and Whipworm) to Egg Flotation Observations. David Elsemore, *IDEXX Laboratories, Inc.* | |
| **97.** Fecal survey for internal parasites of cats in eastern Virginia.<br>Katelynn Monti, *VA-MD College of Veterinary Medicine* | |
| **98.** Demonstration of the Specificity of the Fecal Dx (Hookworm, Ascarid, and Whipworm Antigen) Assays.<br>Jinming Geng, *IDEXX Laboratories, Inc* | |
| **99.** Descriptive findings from the analysis of fecal egg counts from beef cattle of the prairie provinces of western Canada between 2012 and 2014. Felicity Wills, *University of Saskatchewan* | |
| **100.** Phylogenetic Analysis and gis mapping of Rhipicephalus species of Ixodid Ticks of Cattle and Buffalo of District Eshawar Pakistan. Muhammad Imran Rashid, *University of Veterinary and Animal Sciences* | |
| **101.** Prevalence of *Toxoplasma gondii* in mourning doves (Zenaida macroura) from eastern Tennessee.<br>Sawsan Ammar, *University of Tennessee* | |
| **102.** Investigation of the prevalence and distribution of *Echinococcus multilocularis* in wild canids in Ontario, Canada.<br>Jonathon Kotwa, *Ontario Veterinary College* | |
| **103.** Epidemiological risk factors and prevalence of anti-antibodies to *Neospora* spp. in Donkeys from Punjab province, Pakistan,Muhammad Nazir, *Bahauddin Zakariya University, Pakistan* | |
| **104.** *Sarcocystis neurona*: advances in life cycle manipulation.<br>Michelle Carman, *Ohio State University* | |
| **105.** Anthelmintic efficacy of two commercial products against equine cyathostomins (Nematoda: cyathostosminae) was examined using FLOTAC. Bruno henrique Leal e Silva Alves, *Universidade Federal Rural de Pernambuco, Brazil* | |

# NOTES

# 2017 ABSTRACTS

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# Oral Presentations

## Plenary Session: VETERINARY PARASITOLOGY: THE CLIMATE IS CHANGING

### 1

**A crucible of accelerating climate change**

Eric Hoberg, Animal Parasitic Disease Laboratorry, ARS, USDA, Beltsville, MD

Climate provides the stage for the evolutionary and ecological play, ultimately establishing conditions that mediate and shape biodiversity over time. Oscillations in climate historically bracketed extremes of environmental perturbation and stability. Climate establishes the range of permissive environments where life can persist relative to temperature, precipitation, humidity and the availability and states of water. Over recent Earth history of the past 3 million years, cycles of change have emerged from a wobbling climate. Simply these have been the oscillations between cold and warm regimes of varying duration. The biosphere around us, including the diversity of parasites and hosts and the distribution of disease, has and continues to be shaped by dynamic change. It is important to grasp that we now live in a world dramatically different than what has come before. Technological humanity, agriculture and animal domestication all arose in the past 12 thousand years, during an interglacial interval of relatively benign conditions. What we call anthropogenic-forcing has dominated a contemporary regime of increasing atmospheric, oceanic and terrestrial temperatures over the past 250 years. As a general state change, our situation has become so unique and troubling that global system scientists have been compelled to recognize the extent of disruption with a specific name in Earth history- the Anthropocene. Environmental thresholds and tipping points are rapidly being breached due to accelerating climate change and environmental perturbation, as interacting crises for biodiversity, species invasions and emerging infectious diseases. Understanding climate drivers past and present is critical in recognizing and anticipating consequences of shifting distributions and ecological collision of complex faunas including those in the agricultural arena. We remain with a critical need to understand and document pathogen diversity on a global scale. Our world is a future of climate change, perturbation, water and food security, with landscapes and populations in transition.

### 2

**Within-host processes shape host heterogeneity and the impact of climate changes on parasitic infections**

Isabella Cattadori, Penn State University, University Park, PA

Climate changes have been predicted to increase the risk of infection and, with this, epidemic outbreaks and disease severity. However, hosts differ in the way they react to parasites and can alter the net outcome of climate. Immunity is a significant source of heterogeneity among hosts and the questions are: If temperature warming increases exposure to infections, do we see a proportional increase in the parasite burden of immune and non-immune regulated hosts? Does variation among hosts mitigate the climate effects? and What are the long-term consequences of these patterns? We performed field studies, laboratory manipulations and mathematical modeling on a two helminth-herbivore system. We show that temperature warming increases exposure to free-living stages of both helminth species. However, while the intensity of infection in the host population increases proportionally for the parasite that is not regulated by immunity, the immune-controlled helminth exhibits no significant changes. Yet, hosts carry higher burdens at earlier age when immunity is still relatively low and climate-driven exposure is high.

We propose that immunity can mitigate the long-term impact of climate changes but can also increase host heterogeneity by causing greater infections in younger individuals.

## AAVP Student Award

### 3

**Geographic distribution of Lyme borreliosis in North America**

Brian Herrin, Oklahoma State University, Stillwater, OK

Lyme disease is the most commonly diagnosed vector-borne disease in the US, but the ability to accurately diagnose the disease plays a major role in how it is reported. This research is a representation of how canine serology can be used as a tool to further the characterization of Lyme endemic regions of North America and assist medical professionals in promptly and accurately diagnosing this disease. Initially, ticks were targetedly collected from southwestern Virginia to further validate canine serology. Our collections suggest that a population of northern clade *I. scapularis* appears to be expanding southward along the Appalachian Mountains as well as northward into Canada and the ticks are carrying *Borrelia burgdorferi* sensu stricto at a level similar to the endemic regions of the Northeast. Next, canine serology data was utilized to describe social and environmental variables that would indicate where dogs, and thus humans, were most likely to be exposed to *B. burgdorferi* within the New York City Metropolitan Area. While both human case reports and canine seroprevalence trended to increase with increasing forested area, a more complete description of the potentially risky habitats corresponded more closely to canine serology data. The third study was a serosurvey of common vector-borne disease agents of dogs across Canada. The serologic prevalence of antibodies to *B. burgdorferi* in several southeastern provinces was similar to that seen in Lyme endemic areas of the US, reaffirming the disease's endemnicity in these regions. Our description of areas of endemic Lyme borreliosis in Canada provides a base for environmental and temporal studies to describe the expansion of the maintenance system for *B. burgdorferi* north of its historic range. In summary, canine serology is a useful tool for mapping endemic areas of Lyme borreliosis, documenting the expansion of the endemic range, and describing the environments that support the greatest risk of infection to humans and dogs.

## Session 1: Drug Resistance: Nematodes

### 4

**Evaluation of in vitro microfilarial motility to reflect the resistance status of *Dirofilaria immitis* isolates to macrocyclic lactones**

Mary Maclean[1], Molly Savadelis[1], Ruby Coates[2], Michael Dzimiansky[1], Corey Jones[3], Cynthia Benbow[4], Bob Storey[1], Ray Kaplan[1], Andrew Moorhead[1], Adrian Wolstenholme*[1]. [1]University of Georgia, Athens, GA, [2]University of Bath, Bath, United Kingdom, [3]Yazoo City Animal Hospital, Yazoo City, MS, [4]Benbow Veterinary Services, Metairie, LA

Several reports have confirmed that macrocyclic lactone-resistant isolates of *Dirofilaria immitis* are circulating in the United States. However, the prevalence and potential impact of drug resistance is unknown. We wished to assess computer-aided measurements of motility as a method for rapidly assessing the resistance status of parasite isolates. Blood containing microfilariae (Mf) from two clinical cases with a high suspicion of resistance was fed to mosquitoes and the resultant L3 injected into dogs

that were then treated with six doses of Heartgard Plus® at 30-day intervals. In both cases patent heartworm infections resulted and we produced two isolates, Yazoo-2013 and Metairie-2014, which established patent infections despite Heartgard Plus® treatments. Mf isolated from these dogs and other isolates of known resistance status were exposed to varying concentrations of ivermectin in vitro and their motility assessed 24 hours later using computer processed high definition video imaging. Measurements of the motility of Mf of these and other isolates (Missouri, MP3 and JYD-27) following exposure to varying concentrations of ivermectin did not distinguish between susceptible and resistant heartworm populations. Partial inhibition of motility was observed in concentrations of 10µM ivermectin, but never exceeded 50% even in the highest concentration tested (50µM). There was some evidence that the method of Mf isolation had an influence on the motility and drug susceptibility of the Mf. We confirm that drug-resistant heartworms are circulating in the Southern United States, but that motility measurements on microfilariae in the presence of ivermectin are not a reliable method for their detection. This implies that the drug does not kill the microfilariae via paralysis.

## 5

**Using population genetics to explore the origins of macrocyclic lactone resistance in *Dirofilaria immitis***

Julie Sanchez*[1], Melissa George[1], Cassan Pulaski[2], Guha Dharmarajan[3], John Gilleard[4], Ray Kaplan[1].
[1]University of Georgia, Athens, GA, [2]Louisiana State University, Baton Rouge, LA, [3]University of Georgia, Aiken, SC, [4]University of Calgary, Calgary, AB

Canine heartworm (*Dirofilaria immitis*) is the single most important parasite of dogs in the United States. Prevention of heartworm is based on compliant administration of macrocyclic lactone (ML) drugs, and all products are labeled as 100% effective. However, over the past 10-15 years we have seen a dramatic rise in numbers of 'lack of efficacy' cases, and resistance to ML drugs is now proven definitively. The large majority of ML-resistance cases have been diagnosed in dogs living in the Mississippi Delta region; however, at present the spatial distribution of drug-resistant heartworm genotypes remains uncertain. This project aims to understand the epidemiology of resistance by using genetic approaches to investigate the origins and spread of resistance. We developed a panel of highly polymorphic microsatellite markers specific to *D. immitis* to examine the population genetics of canine heartworm.Twenty-four markers that successfully amplified at the expected size were initially confirmed using pools of 500 microfilariae from three susceptible and two resistant laboratory isolates of *D. immitis*. Fragment analysis was conducted using the ABI 3730xl system, and a total of 15 novel highly polymorphic markers were identified. These markers were used in combination with two previously published microsatellite markers to screen microfilariae from three susceptible and two resistant laboratory isolates, and from 32 high-suspect resistant and 10 likely-susceptible field isolates, based on case history and/or results of microfilariae suppression tests. Analyses are currently in progress. Results from these analyses will permit measurement of genetic sub-structuring and provide insights into the genetic relationship between isolates based on both ML susceptibility/resistance and geography. Understanding the genetic processes involved in ML resistance will be critical to making predictions about the spread of drug resistance, and the effect of various interventions on reducing the prevalence and rate of spread of drug-resistance genes in natural *D. immitis* populations.

## 6

**_Dirofilaria immitis_ JYD-34 isolate: whole genome analysis**

Roger Prichard*[1], Cristina Ballesteros[1], Catherine Bourguinat[1], Kathy Keller[1], Christrian Epe[2], Brenda Bondesen[2], Yovany Moreno[2]. [1]McGill University, Sainte Anne-de-Bellevue, QC, [2]Boehringer Ingelheim Animal Health, Duluth, GA

Macrocyclic lactones (ML) are used for chemoprophylaxis for heartworm in dogs and cats. Recently, ML resistance has been confirmed in *Dirofilaria immitis*. A *D. immitis* isolate, JYD-34 has been found to be highly resistant to ML preventives. To advance efforts to develop molecular markers for ML resistance and to understand possible mechanisms of resistance, it was of interest to compare the genetic profile of JYD-34 with known ML-susceptible isolates. In this study, the 90Mbp whole genome of the JYD-34 isolate was sequenced. This genome was compared using bioinformatic tools to whole genomes of 4 susceptible *D. immitis* populations, as well as 4 suspected loss-of-efficacy (LOE) *D. immitis* populations. Fixation indexes (Fst) allow the genetic structure of different populations to be compared at the level of single nucleotide polymorphisms (SNPs) across the genome. The Fst analysis on the *D. immitis* isolates confirmed that the JYD-34 isolate has a genome similar to LOE isolates previously investigated, and dissimilar to the susceptible isolates. At the loci that had previously been identified as potential markers for ML resistance in *D. immitis*, JYD-34 had a genetic profile similar to a previously analyzed isolate that had been confirmed to have reduced susceptibility to MLs. In order to begin to understand genetic changes which may be causes of ML resistance, the genome of the JYD-34 worms that survived chemoprophylaxis (the resistant portion of the JYD-34 isolate) were also sequenced across the genome. These results provide additional evidence for the link between genotype and the reduced susceptibility phenotype, and indicate biological structures, such as neuro receptors and cell-cell junctions, that may be implicated in ML resistance in *D. immitis*. This research was sponsored by Boehringer Ingelheim Animal Health.

## 7

**Heartworm preventive drug 'lack of effectiveness' claims submitted to the FDA (2004-2015): an analysis of reports and further application**

Cassan Pulaski*[1], Renee Shibukawa-Kent[2], Susan Bright-Ponte[2], Hesha Duggirala[2], John Baker[2], John Malone[1], Ray Kaplan[3]. [1]Louisiana State University School of Veterinary Medicine, Baton Rouge, LA, [2]U.S. Food and Drug Administration, Rockville, MD, [3]University of Georgia College of Veterinary Medicine, Athens, GA

In 2005, Hampshire published the first peer-reviewed article on the potential emergence of macrocyclic lactone (ML) resistance in *Dirofilaria immitis* based on lack of effectiveness (LOE) claims submitted to the Center for Veterinary Medicine (CVM) within the U.S. Food and Drug Administration (FDA). Over the next 10 years, the veterinary community would continue to see increasing numbers of suspect ML LOE cases, predominantly focused in the Lower Mississippi Delta region. Currently, however, the extent of ML resistant heartworms (HWs) is unknown, with information lacking on prevalence and geographic range of such cases. The objective of this study is to analyze ML LOE reports submitted to CVM since 2005, in order to identify possible changes, patterns, and interactions found between and within cases. To date, approximately 45,000 ML LOE claims have been reported to CVM, with each report assigned a causality score, ranking the probability of true ML drug ineffectiveness. A comprehensive analysis is underway searching for epidemiologic trends and geospatial patterns among the reports, with a focus on animal signalment, space-time relationships, and the identification of possible 'hot spots.' A statistically significant random sample of reports has been selected, and an

analysis of these will be presented using the same techniques that will be applied to all 45,000 reports once they have been finalized. The outcome of this project will not only help elucidate trends of ML resistance in HWs in the USA, but similar approaches can be applied to monitor drug resistance in other parasites affecting other countries. Additionally, this data is being used to validate geospatial prediction models of ML resistance, specifically in Louisiana. The creation of these maps is currently underway, as well as mosquito vector trapping based on related risk models. If available at the time of the symposium, this data will also be presented.

## 8

**Prevalence of gastrointestinal nematode resistance to avermectin anthelmintics on beef cattle operations in Georgia**

Kelsey Paras*, Melissa George[1], Sue Howell[1], James Collins[1], Bob Storey[1], Ray Kaplan[1]. [1]University of Georgia, Athens, GA,

Anthelmintic resistance in gastrointesintal nematodes (GIN) is a worldwide problem in all livestock systems, with most reports of resistance in cattle parasites being to the macrocyclic lactone (ML) drug class. Several prevalence studies performed internationally demonstrate that anthelmintic resistance in cattle parasites is a growing problem; however, no studies have been performed in the US. Twelve cow-calf farms, throughout Georgia are planned for inclusion in the study, and to date, six farms are completed. On each farm we performed fecal egg count reduction tests (FECRT) and coprocultures using three different treatments: eprinomectin pour-on (Eprinex®, Merial, Duluth, GA, USA), doramectin injectable (Dectomax®, Zoetis, Kalamazoo, MI, USA), and a combination of doramectin injectable and oral fenbendazole (Safe-guard®, Merck, Madison, NJ, USA). It is not possible to differentiate trichostrongyle eggs morphologically, therefore, we assigned eggs to parasite genus proportionally based on larval identifications, and then calculated genus-specific FECR. Overall FECR ranged from 31.3-96.7% (mean=70%) for eprinomectin, and 47.8-97.9% (mean=75.3%) for doramectin; these results were not significantly different (p=0.21). Four farms exhibited resistance to both individual therapies, one had resistance to eprinomectin and suspected resistance to doramectin, and one farm had GIN susceptible to both individual treatments. GIN showed susceptibility to combination therapy on all farms (mean FECR=98.5%), and this was significantly higher than for both eprinomectin and doramectin (p=0.029, 0.04). ML-resistant *Cooperia* were present on 5 of the 6 farms, and one farm also had ML-resistant *Ostertagia* (FECR=84.7%, 90%) and *Haemonchus* (FECR=16.3%, 45%) for EPR and DRM, respectively. These data demonstrate that resistance to ML drugs is highly prevalent in *Cooperia* on beef farms in Georgia. The diagnosis of resistance in *Cooperia, Ostertagia* and *Haemonchus* all on the same farm is a clear indication that anthelmintic resistance is reaching important levels that threaten the health and productivity of cattle in the United States.

## 9

**A 16-year retrospective analysis of anthelmintic resistance on small ruminant farms in the United States.**

Sue Howell*, Bob Storey, James Collins, Ray Kaplan. University of Georgia, Athens, GA

The DrenchRite© larval development assay (LDA) is a diagnostic bioassay that measures and detects resistance to benzimidazoles, levamisole, ivermectin, and moxidectin. From 2000-2016 we performed DrenchRite© LDA on 291 small ruminant farms in 40 of 50 USA states. We then performed a retrospective analysis of these data to investigate changes in prevalence and levels of anthelmintic resistance in *Haemonchus contortus* over this period. For analyses, data were grouped by 5-6 year

intervals (2000-2005; 2006-2010; 2011-2016). Resistance to both benzimidazoles and ivermectin was highly prevalent; e95% of both sheep and goat farms demonstrated resistance to benzimidazoles, and e92% and e56% of goat and sheep farms, respectively demonstrated resistance to ivermectin at all time intervals. Levamisole resistance was less prevalent with goat farms ranging from 21% to 41% and sheep farms ranging from 24% to 36% throughout the 16-year period. The greatest changes were for moxidectin, and these were significantly greater for goats than for sheep ($p<0.0001$). The first cases of moxidectin resistance diagnosed on goat and sheep farms were in 2001 and 2002, respectively. Prevalence of resistance to moxidectin progressively and dramatically increased over the next two time periods (2006-2010, 2011-2016) on both goat (40%, 59%) and sheep (13%, 26%) farms. Coincident with this increase in prevalence, levels of resistance also increased from a mean $IC_{50}$ of 395 nM and 125 nM (2000-2006) to 1845 nM and 703 nM (2011-2016) for goat and sheep farms, respectively. Additionally, total anthelmintic failure (resistance to all 3 classes plus moxidectin) increased from 8% to 39% for goat farms and 3% to15% for sheep farms. These data provide interesting insights into changes occurring over time. Though prevalence and levels of resistance are lower on sheep as compared to goat farms, these data indicate a severe situation now exists in the USA for both species.

## Session 2: Immunology

### 10

**Ovine-derived neutrophils preferentially form NETs in response to different life stages of *Haemonchus contortus* in vitro.**

Javier Garza*, Scott Bowdridge. West Virginia University, Morgantown, WV

Neutrophil extracellular traps (NET) form in response to *Haemonchus contortus* L3 in a breed-dependent manner. Neutrophils are present during adult stages of infection, but their function has not been assessed. The objective of this study was to determine the ability of neutrophils from parasite-resistant and -susceptible sheep to form extracellular traps in response to larval or adult *H. contortus* whole worm antigen. Neutrophils were isolated from *H. contortus* primed St. Croix and Suffolk lambs and incubated with either whole worm lysates from L3 (CLA) or adults (CWA), phorbol myristate acetate (PMA), or complete media (CM) for 12 hours in black 96 well plates at 37°C with 5% $CO_2$. Release of extracellular DNA into the supernatant was evaluated fluorometrically using a Sytox Green assay and data were analyzed using two-way ANOVA with Tukey's procedure for means comparison. Extracellular trap formation was confirmed using various forms of microscopy through co-localization of extracellular DNA, histone H4, and neutrophil elastase. When incubated with CLA, a significant increase in extracellular DNA was observed between primed St. Croix and Suffolk neutrophils incubated with CLA (data), both of which were greater than CM ($P < 0.001$). Culture with CWA revealed that extracellular DNA was increased 1.5-fold in both St. Croix and Suffolk neutrophils compared to CM, but was significantly lower than neutrophils exposed to CLA ($P < 0.001$). These data indicate that NET formation is a host defense mechanism associated with larval, but not adult stages of *H. contortus*. Formation of these traps may be critical for larval clearance from the host, ultimately reducing adult establishment.

## 11

**Effects of ovine monocytes on *Haemonchus contortus* larvae in vitro reveal alternative activation state.**

Elizabeth Shepherd*, Scott Bowdridge. West Virginia University, Morgantown, WV

Peripheral blood mononuclear cells (PBMC) have been shown to significantly increase *Haemonchus contortus* larval morbidity in vitro. To determine which cell subset is responsible for larval morbidity, monocytes ($CD14^+$) were positively selected from STC- or SUF- derived PBMC using magnetic cell separation, and negatively selected lymphocytes ($CD14^-$) cells were also retained for experiments. Cells from each breed were plated at a density of 5 x $10^6$ cells / ml with 100 $L_3$ per well in a 24-well plate, and incubated for 18hr at 37°C and 5% $CO_2$. Morbidity was assessed using an ATP Assay and motility was analyzed using tracking software. STC-derived monocytes significantly reduced larval ATP (0.02 µM ATP) compared to SUF-monocytes (0.07 µM ATP) and lymphocytes from either breed (STC: 0.09 µM ATP and SUF: 0.11 µM ATP) ($P < 0.001$). ATP of larvae exposed to SUF-derived lymphocytes was not significantly different than untreated larvae (0.20 µM ATP). Monocytes derived from STC or SUF breeds reduced larval motility (18 µm and 13 µm respectively) comparable to STC-derived PBMC (18 µm), and significantly reduced motility compared to untreated larvae (38 µm) and SUF-derived PBMC (27 µm) ($P < 0.05$). STC-derived monocytes express 3-fold higher IL-4 mRNA in response to crude larval antigen (CLA) than those of SUF sheep ($P < 0.05$), and both breeds express equivalent levels of MRC1 and IL-13. Additionally, STC monocytes produced greater levels of arginase in response to CLA than LPS (4.0 U/L and 2.2 U/L respectively) ($P < 0.05$), whereas no differences were detected in SUF monocytes (CLA: 4.4 U/L and LPS: 4.3 U/L). Taken together, these data indicate monocytes are major effector cells and may become alternatively activated when exposed to CLA.

## 12

**Ovine neutrophils rapidly produce Interleukin-4 (IL-4) in response to *Haemonchus contortus* larval antigen in vitro**

Denzel Middleton*, Javier Garza, Scott Bowdridge. West Virginia University, Morgantown, WV

Greater IL-4 production during early *Haemonchus contortus* infection in parasite-resistant St. Croix (STC) sheep has been previously reported, yet the cell type responsible for early IL-4 production is currently unknown.Studies measuring cellular immune response to *H. contortus* demonstrated greater infiltration of neutrophils to the abomasum of STC by 3 days after infection as compared to parasite susceptible Suffolk sheep (SUF). The role of neutrophils has recently been expanded to also contribute Th2 responses in human and murine models. Therefore, we hypothesize that neutrophils are an early source of IL-4 that provide initial stimuli for Th2 activation during *H. contortus* infections. Neutrophils from STC and SUF were plated at 100,000 cells/well and co-cultured with either complete media (CM), crude larval antigen (CLA), or crude worm antigen (CWA) at a concentration of 20 µg/mL and incubated for 30 minutes, 1, 3, and 6 hours at 37ºC and 5% $CO_2$. Supernatant was collected and IL-4 was measured using an ovine-specific enzyme-linked immunosorbent assay (ELISA). Neutrophils from either breed exposed to CLA produced significantly higher levels of IL-4 by 30 minutes (225 pg/mL and 223 pg/mL) when compared to neutrophils cultured with CWA (19 pg/mL and 21 pg/mL) ($P <0.001$). No differences in IL-4 were observed between time points. These data suggest that neutrophils preferentially produce IL-4 in response to larval rather than adult antigen, and may contribute to the initiation of Th2 responses during *H. contortus* infection.

## 13

**Antigenic epitopes of *Haemonchus contortus* third stage larval cuticle are recognized by antibody derived from parasite-resistant sheep.**

Brynnan Russ*, Javier Garza, Scott Bowdridge. West Virginia Univeristy, Morgantown, WV

Neutrophils and peripheral blood mononuclear cells (PBMC) derived from parasite-resistance sheep are capable of binding *Haemonchus contortus* third stage larvae (L3) cuticle. Cellular binding is associated with a significant reduction in L3 motility and an increase in L3 morbidity. Serum of both resistant and susceptible breeds caused L3 aggregation, but did not cause aggregation in exsheathed L3 (XL3) or L4. Antibody-mediated aggregation of L3 indicates recognition of cuticular antigen. Thus, the aim of this study was to determine breed differences in antibody-mediated recognition of *H. contortus* L3 cuticular protein antigens. Western blots were performed using homogenized XL3, L3, and cuticle antigen. The blot was probed with serum from primed St. Croix (PH) or Suffolk (PW) as the primary antibody and antibody isotypes were detected using fluorescently labelled anti-goat IgG or anti-sheep IgA. PH IgG robustly recognized a 35kDa protein in XL3, L3, and cuticle samples, indicating strong antibody production to this protein. This band was also recognized at a lower intensity by PH IgA in XL3 and L3, but not cuticular sample. PH IgA bound to a greater number of proteins at a higher level than PW IgA. Specifically, PH IgA's strongest binding was to a 52kDa cuticle protein not present in XL3, L3 samples, or recognized by IgG. These data indicate differences in antibody response to *H. contortus* L3 component antigens and breed-dependent antibody responses. Further elucidation of these larval proteins may serve as unique epitopes for potential vaccine development.

## 14

**Histopathologic Evaluation of Local Inflammatory Responses Surrounding Encysted Larval Cyathostomins in 36 Moxidectin and Fenbendazole Treated Ponies**

Ashley Steuer*[1], Alan Loynachan[2], Martin Nielsen[1]. [1]University of Kentucky, Gluck Equine Research Center, Lexington, KY, [2]University of Kentucky, Veterinary Diagnostic Laboratory, Lexington, KY

Cyathostomins are pervasive parasites of horses that can cause a potentially life threatening disease, "larval cyathostominosis," which occurs when large numbers of encysted larvae synchronously excyst from the wall of the large intestine and is fatal in 50% of cases. Currently, moxidectin and fenbendazole are labeled to treat the encysted stages. There is limited knowledge of the local inflammatory response to the larvae and to the two treatments. This study evaluated the local inflammatory response to cyathostomin larvae and to larvicidal treatment at 2 and 5 weeks post treatment. 36 ponies with naturally acquired cyathostomin infections were randomly allocated to 3 groups: Group 1, fenbendazole at 10mg/kg for 5 days, Group 2, Moxidectin at 0.4mg/kg, and Group 3, untreated controls. Tissue samples from the cecum and dorsal and ventral colons were used for histopathological evaluation. Scores were given between 0-3 for all inflammatory cell types, as well as fibrous connective tissue. Larvae observed were counted and classified by stage, and mucosal ulcerations and submucosal granulomas were also enumerated. Average macrophage score was higher in Group 2 than Group 1 ($p=0.0185$) and the control group had a higher activated macrophage score than both treatment groups ($p=0.0104$, $p=0.0004$). T-lymphocyte scores were elevated in group 2 when compared to the control group ($p=0.0069$). Goblet cell hyperplasia scores were higher at 5 weeks post treatment than 2 weeks post treatment ($p=0.0047$) and were elevated in the ventral colon compared to the dorsal colon ($p=0.0301$). Eosinophil scores were elevated surrounding degenerative larvae when compared to intact larvae ($p=0.0001$). Mucosal ulcerations were found only in the control group at 2 weeks post treatment. This study illustrates there

were differences between groups 1 and 2 in relation to the control group. Inflammatory reactions also differed between organs, location in the tissues and in relation to larval stage.

## 15

**Histopathologic changes at the tick-host interface of *Amblyomma americanum* on tick-naïve domestic cats (*Felis catus*)**

Jennifer Thomas*[1], Joanne Mansell[1], Alison Diesel[1], Adam Patterson[1], Mason Reichard[2]. [1]Texas A&M University, College Station, TX, [2]Oklahoma State University, Stillwater, OK

Detailed characterization of the relationship between a tick species and the host immune system is critical for understanding the host response to the ectoparasite and provides insight for pathogen transmission. The purpose of the present study was to characterize the histopathologic changes induced by adult *Amblyomma americanum* bites on tick-naïve domestic cats. Six purpose bred domestic cats (3 males, 3 females) were used in this study. Skin biopsies were collected prior to tick infestation, and each cat was infested with 50 laboratory-reared, pathogen-free *A. americanum* adults. Subsequent biopsies were collected at 24, 48, and 96 hours post-infestation at tick-bite sites. By 24 hours post-infestation, mild, focal epidermal necrosis was observed, with a minimal increase in dermal inflammatory infiltrates. The tick feeding cavity extended through the epidermis into the dermis within 24 hours of infestation. By 48 hours post-infestation, inflammation extended into the dermis and subcutis; the predominant patterns included a moderate perivascular neutrophilic dermatitis and a moderate diffuse neutrophilic panniculitis. Coagulated collagen degeneration was observed in the dermis by 48 hours. By 96 hours post-infestation, a focally severe neutrophilic dermatitis and panniculitis was observed, with focal areas of necrosis and fibrin deposition extending through the subcutis into the muscle band of the deep subcutis. The histopathologic changes observed in this study incorporated specific responses previously observed at the tick-host interface of dogs, cattle, rodents, and lagomorphs.

# Session 3: Parasite Control - 1; Drug Therapy

## 16

**Macrocyclic lactone (ML) anthelmintics lack meaningful in vitro activity against L3 and L4 stages of both ML-susceptible and ML-resistant *Dirofilaria immitis***

Pablo Jimenez Castro*, Tiffany Yue, Ray Kaplan. University of Georgia, Athens, GA

Macrocyclic lactone (ML) anthelmintics are the only treatment available for preventing vascular infection with *D. immitis*. However, the mechanism of action of ML drugs against *D. immitis* remains unclear. In this study, we tested the in vitro dose response of both L3 and L4 stages of ML-susceptible (Missouri strain) and ML-resistant (Metairie-2014 strain) *D. immitis*, using both ivermectin (IVM) and eprinomectin (EPR) at concentrations ranging from 0.625 to 20 µM. L3 were isolated from mosquitoes and used directly, or were cultured for 6 days to obtain L4 before adding drug. Culture media was composed of NI media with 10 % FBS, supplemented with antibiotics. Motility measurements were made every 24hr for 4 days using computer processed video imaging (Worminator system), and a nonlinear regression model was fit to the dose response data. Mean IC50 values for IVM and EPR were 4.08, 7.45, and 9.54, 9.45 µM for the susceptible and resistant strain, respectively for L3, and 7.54, 13.41, and 8.90, 4.64 µM, respectively for L4. Maximal inhibition of motility varied from 68-92% with no apparent biological differences between strains or larval stages. In vitro exposure to ML failed to achieve complete inhibition in the ML-susceptible strain, even at the highest concentration tested (20

μM), which is >5,000X times higher than the in vivo plasma concentration following a preventive dose of IVM. Additionally there were no apparent differences in dose response between ML-susceptible and ML-resistant strains. These data, using the stages of *D. immitis* targeted by monthly preventive doses of ML, strongly suggest that both the mechanisms of action and of resistance in *D. immitis* are not mediated through paralytic effects, and that ML drugs do not demonstrate meaningful in vitro activity against *D. immitis*.

## 17

**Moxidectin and fenbendazole treatment of equine cyathostomins – adulticidal/larvicidal efficacy, egg reappearance period, and species composition.**

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Cyathostomin nematodes are ubiquitous in grazing horses worldwide, and anthelmintic resistance in these parasites is well established. The aim of this study was to investigate moxidectin (0.4 mg/kg) and fenbendazole (10 mg/kg daily for 5 consecutive days) efficacy against encysted larval stages and compare these regimens at 2 and 5 weeks post treatment while determining cyathostomin species associated with shortened egg reappearance periods and documenting species exhibiting decreased susceptibility to either regimen. Thirty-six ponies were randomly allocated to moxidectin, fenbendazole, and control groups with half of each group euthanized 2 weeks post-treatment, and the remainder necropsied after 5 weeks. Luminal and mucosal worm counts were obtained at both time intervals and strongyle egg counts were determined at weekly intervals throughout the study. Two weeks post-treatment, mean reductions of early third stage larvae (EL3) were 60.8% and 50.4% for moxidectin and fenbendazole, respectively. At 5 weeks, the respective efficacies were 71.8% and 51.3%. Efficacies against late third stage and fourth stage larvae (LL3/L4) were 74.6% and 70.8% for moxidectin and fenbendazole, respectively, at 2 weeks post treatment, whereas very low numbers were found in all three groups at the 5-week interval. Moxidectin and fenbendazole reduced luminal worm counts by 98.3% and 93.2% at 2 weeks following administration, whereas both treatment groups had increased counts three weeks later (p=0.0415). A moxidectin egg reappearance period of 4 weeks was associated with luminal L4s surviving treatment, and species contributing to this were *Cyathostomum catinatum*, *Cylicostephanus longibursatus*, *Cylicocyclus* (*Cyc*.) *ashworthi* and *Cyc. nassatus.* This study documented larvicidal efficacy of fenbendazole much lower than historical standards, survival of luminal immatures (L4) following moxidectin administration, and new information about cyathostomin species associated with these phenomena.

## 18

**Emodepside: Activation of SLO-1 K currents in *Brugia malayi* and *Xenopus* oocyte expressed channels**

Richard Martin*, Sudhanva Kashyap, Saurabh Verma, Alan Robertson. Iowa State University, Ames, IA

Emodepside (Profender$^{R}$) is a useful anthelmintic for dogs given orally, and for cats applied as a spot-on. Emodepside has a medium spectrum of action, being effective against gastro-intestinal roundworms. To date, there have been few concerns about acquired resistance. We have been examining its effects and modes of action in filarial parasites, to see if its spectrum of action could be extended. Using *Brugia malayi,* we found that emodepside produces a concentration-dependent inhibition of motility in adult *B. malayi* parasites with an $IC_{50}$ of 0.6 μM. Under patch-clamp, we found that *B. malayi* muscle cells

responded to bath application of emodepside with outward potassium current amplitude that was concentration dependentwith an $EC_{50}$ of 0.8 µM. This potassium current was inhibited by the selective SLO-1 K channel blocker, iberiotoxin (100nM). Emodepside also increased voltage-activated potassium currents of *B. malayi* muscle. These two effects on the potassium currents appear to explain the inhibitory effects of emodepside on parasite motility. Expression of the SLO-1f spliced variant of the SLO-1 channel in *Xenopus* oocytes produced an outward current that was activated by emodepside in a concentration-dependent manner, but it had a higher $EC_{50}$ of 4.8 µM. The difference between the *B. malayi*muscleSLO-1 K channels and the expressed SLO-1 K channel was a 6-fold change in potency. Interestingly, the expressed SLO-1 K channels also lost their sensitivity to iberiotoxin. We are investigating reasons for this change in potency and theloss of sensitivity to iberiotoxin. Factors that affect SLO-1 K channelsensitivitiesto emodepside will also influence the sensitivities of different nematodes.

Martin, RJ, Buxton, SK, Neveu, C, Charvet, CL, Robertson, AP (2012) Emodepside and SLO-1 potassium channels: a review. *Experimental Parasitology.* **32**, 40-46.

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## 19

**Selective therapy to control cyathostomins in Thoroughbred mares**

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Cyathostomins are the most prevalent endoparasites of equines. The traditional approach for control involves administration of anthelmintics to all animals at regular treatment intervals. Due to frequent treatments, cyathostomins have developed resistance to all anthelmintic drug classes. Selective therapy is recommended to decrease the selection pressure for resistance, treating only those horses identified with a fecal egg count (FEC) above a pre-established limit. Several studies reported the applicability of this method in adult horse populations; however, this approach is not widespread in many countries of South America. The objective of this study was to evaluate the use of selective therapy in Thoroughbred mares on a stud farm located in São José dos Pinhais, Paraná, Brazil. For 13 months, 28 mares, with a mean age of 10.1 years, were evaluated monthly through FECs using the Mini-FLOTAC technique and coprocultures were performed to differentiate strongyle L3 larvae. Whenever a horse's FEC exceeded 500 eggs per gram, it received ivermectin/praziquantel. At completion of the study all horses underwent a serum ELISA analysis for detection of cyathostomin infection. A total of 31 anthelmintic treatments were carried out during the study, where 39% (n=11) of the horses received no anthelmintic treatment, 25% (n=7) received only one treatment, and 36% (n=10) received multiple treatments. The coprocultures revealed that 98% of the larvae cultured were Cyathostominae and 2% were Strongylinae. The ELISA test found 63.63% of the horses to be positive and 36.37% negative for encysted cyathostomin larvae. These results illustrate that the majority (64%) of the horses require a maximum of 1 treatment to achieve a FEC of less than 500 eggs per gram. This study also suggests that selective therapy decreases the treatment intensity.

## 20

**A one-herd evaluation of internal and external parasite controls on Arkansas stocker cattle.**

Eva Wray*, Chris Tucker, Jase Ball, Jeremy Powell, Jana Reynolds, Pete Hornsby. University of Arkansas, Fayetteville, AR

A long-standing recommendation from this lab is for cattle farmers to conduct fecal egg count reduction tests (FECRTs) to determine if their anthelmintics are "working"; thereby, eventually, finding an effective (cost-worthy) parasiticide. Admittedly, the FECRT is an imperfect tool for evaluating anthelmintics, but it remains the only readily accomplished, *in vitro* method available. In the way of "practicing what we preach", three consecutive FECRTs, with coincident fly (*Haematobia irritans*) counts, were conducted on a single herd of University stocker cattle (n=88). The same calves were treated on three separate occasions: day 0 with Eprinomectin LongRange, Cydectin Injectable or Cydectin Pour-on, day 56 with Ivomec Injectable or Ivomec Injectable with Synanthic Oral Suspension and on day 84 with Levamisole drench. Treatments were assigned after appropriate blocking and randomizations. Egg count reductions were calculated from counts determined on the day of treatment. The day 56 Synanthic with Ivomec treatment group displayed a 14-day post-treatment FECR of 99%, but at 28 days post-treatment, the FECR % decreased to 74. The Levamisole treatment group displayed a 98% FECR at 14 days post-treatment. No other treatments were followed by a FECR % > 89. Treatment with Eprinomectin LongRange did significantly decrease horn fly infestations. Judging from coproculture harvests and $L_3$ identifications, the Cooperiads accounted for the majority of the strongyle eggs counted.

# Session 4: Molecular and Biochemical - 1

## 21

**Utilizing next generation sequencing to discover highly repetitive DNA sequence targets for real-time PCR diagnosis of *Heterobilharzia americana***

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*Heterobilharzia americana* is a trematode parasite of dogs in the southeastern United States that causes intestinal, hepatic, and pancreatic disease. Low and intermittent fecal egg shedding necessitate a highly sensitive diagnostic assay. Mitochondrial and ribosomal DNA sequences are typical targets for PCR diagnosis of parasites; however, cross-reactivity may occur between closely related parasites. Non-coding highly repetitive DNA sequences make up a substantial portion of helminth genomes and are highly divergent between closely related species. We utilized next generation sequencing technology and the Galaxy-based RepeatExplorer computation pipeline to discover highly repetitive DNA sequences in the *H. americana* genome. We developed a novel probe-based real-time PCR diagnostic assay targeting these highly repetitive sequences. No DNA amplification was detected when testing DNA of common parasites. Out of 83 fecal samples tested, 24 were positive by real-time PCR. We compared these data to previous results of a conventional PCR assay (cPCR) targeting 18S rDNA (17 positive) and a fecal saline sedimentation test (14 positive). The real-time PCR and cPCR assays had a 68.3% positive agreement, 89.6% negative agreement, and 84.3% overall agreement (kappa 0.5829). The real-time PCR assay detected 10 positive samples that were negative by cPCR. Two of those 10 samples were also positive by fecal saline sedimentation. All fecal saline sedimentation positive samples

were positive by the real-time PCR assay. While the absence of a true gold standard for detection makes it impossible to rule out the possibility of off-target amplification, these real-time PCR only positive cases likely represent an increase in sensitivity by the novel assay. Given the improved target, and use of real-time PCR, such an improvement is not unexpected. This efficient method of determining high copy DNA sequences in the genome can be used to develop highly sensitive and specific PCR assays for the diagnosis of other parasitic infections.

## 22

**Does the benzimidazole drug fenbendazole have multiple targets in nematodes?**

Susan Stasiuk*, Mathew Workentine, John Gilleard. University of Calgary, Calgary, AB

Benzimidazoles (BZ) are an important class of broad-spectrum anthelmintic, widely used for parasitic nematode control in livestock and are one of the few anthelmintic classes available for the control of human soil-transmitted helminths. BZs act by binding to ² -tubulin monomers and disrupting their polymerization into microtubules. In the case of *C. elegans* and trichostrongylid nematodes, only one target has been identified in each case to date, the *ben*-1, and isotype-1 ² -tubulin genes, respectively. We have been investigating the effect of benzimidazole drugs on a *C. elegans ben*-1 mutant strain, CB3474 *ben-1(e1880)III*, primarily as an approach to elucidate xenobiotic responses but also to investigate the potential existence of additional targets. We have examined the global transcriptomic response in this strain to five different BZ drugs using RNAseq analysis. This revealed that relatively few genes were differentially regulated greater than 2-fold ($p<0.05$) for albendazole (197 upregulated, 69 downregulated), thiabendazole (325 upregulated, 226 downregulated), mebendazole (161 upregulated, 18 downregulated), oxfenbendazole (515 upregulated, 1977 downregulated). The most highly upregulated genes encoded xenobiotic metabolizing enzymes. In contrast, fenbendazole exposure resulted in 2448 upregulated and 1752 downregulated differentially expressed genes. Examination of the Biological Gene Ontology (GO) suggests additional processes are enriched in fenbendazole exposed worms, in addition to xenobiotic responses. *C. elegans* Tissue Enrichment Analysis (TEA), suggests the nervous system is enriched for genes which are upregulated, and oocytes and spermatheca are enriched for genes which are down-regulated. We have examined the effect of benzimidazoles on *C. elegans* CB3474 *ben-1(e1880)III* mutants, and found that fenbendazole, but not the other BZs drugs, inhibits egg production in hermaprodites. Together, this evidence suggests that fenbendazole may have secondary target(s) in *C. elegans*, in addition to the *ben*-1 ² - tubulin, that is distinct to those of other benzimidazole drugs.

## 23

**The use of deep amplicon sequencing for wide-scale scanning of ovine parasitic nematode populations for benzimidazole resistance mutations**

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Recent developments in next-generation sequencing technologies provide a powerful set of tools to screen parasitic nematode populations for anthelmintic resistance mutations and study the molecular epidemiology of resistance. This approach has many advantages compared to previous approaches, including greater repeatability, higher throughput and higher sensitivity. Multiplexing of barcoded primer combinations allows the sequencing of hundreds of samples in a single Illumina MiSeq run, making it increasingly affordable to undertake large scale surveys. We have developed and optimized

primer sets for use in deep amplicon sequencing of isotype-1 B tubulin gene fragments encompassing the three benzimidazole resistance-conferring SNPs (codons 167, 198 and 200) from *Haemonchus contortus, Cooperia* sp, *Trichostrongylus colubriformis* and *Teladosargia circumcincta.* We have also developed a bioinformatic pipeline to filter deep amplicon sequencing data and determine the frequency of the specific single nucleotide polymorphisms (SNPs). We have applied these tools to screen a large number of parasite populations from UK and western Canadian sheep farms for benzimidazole-associated resistance mutations. We will present this data and describe how this new approach now allows us to simultaneously screen multiple parasite species at multiple SNP positions in large numbers of parasite populations extracted from fecal samples and undertake molecular epidemiology studies.

## 24

**Single Nucleotide Polymorphisms in immune gene transcripts are associated with T helper type 2 response in St. Croix sheep**

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Peripheral blood mononuclear cells (PBMC) of parasite-resistant St. Croix sheep upregulate T helper type 2 (Th2) immune genes in response to *Haemonchus contortus* antigen. PBMC from St. Croix and parasite susceptible Suffolk sheep generate similar levels of *Il4* mRNA (8.42 vs 9.70, $P > 0.05$); however, downstream Th2 gene activation is not observed in Suffolk PBMC cultured with *H. contortus* antigens. Whole transcriptome analysis (n = 3 / breed) revealed Single Nucleotide Polymorphisms (SNP) within the high affinity IL-4 receptor (IL4R±) and NLRP3 genes in St. Croix PBMC, which are associated with downstream Th2 upregulation. IL4R± interaction with IL-4 is required for further Th2 activation. Seven SNP were discovered in the *Il4ra* transcript of St. Croix cells, while no differences between Suffolk and the reference genome (Texel) were found. Three SNP were revealed in the *Nlrp3* transcript in St. Croix PBMC, which was one of the most highly upregulated genes found upon RNA-Sequencing compared to Suffolk ($P = 7.42 \times 10^{-5}$). Single nucleotide polymorphisms in these important immune genes may be responsible for lowered fecal egg count and parasite resistance to *H. contortus* continually documented in St. Croix hair sheep.

## 25

**Defining global transcriptomic differences between different strains of *Haemonchus contortus* in the face of high levels of sequence polymorphism**

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The extent to which global gene expression varies between different strains of parasitic nematodes has been little investigated. This represents a major knowledge gap since gene expression differences could underlie many phenotypic traits. Furthermore, differential gene expression is commonly used to implicate genes in anthelmintic drug resistance. However, differences in the expression of individual genes cannot be interpreted without an understanding of global transcriptomic differences.

*Haemonchus contortus* is an important livestock pathogen and model to study parasite biology and drug resistance. Here we present a detailed RNAseq whole transcriptome comparison of three genetically diverse *H. contortus* strains – MHco3(ISE) (ivermectin sensitive), MHco4(WRS) (ivermectin resistant), and MHco10(CAVR) (ivermectin resistant). We demonstrate that high levels of sequence polymorphism

affects read-mapping efficiency to coding regions leading to overestimation of transcriptional differences by standard RNAseq analysis pipelines. We demonstrate that adjusting read-mapping polymorphism allowance can compensate for biases to allow reliable identification of differentially expressed genes. We have found significant differences in the transcriptome between the three strains: 1125, 1498, and 824 genes were found to be differentially expressed in the MHco3(ISE) vs. MHco4(WRS), MHco3(ISE) vs. MHco10(CAVR), and MHco4(WRS) vs. MHco10(CAVR) comparisons respectively. Of these 491, 297, and 155 genes were differentially expressed in MHco3(ISE), MHco4(WRS) and MHco10(CAVR) respectively vs. both opposing strains, suggesting MHco3(ISE) as the most transcriptionally diverged. Known ligand-gated ion channel and ABC transporter proteins were assessed with 14 and 15 genes of these groups respectively being differentially expressed in at least one of the resistant strains. Notable differentially expressed genes included *lgc-55* and *pmp-6* which are differentially expressed in both drug resistant strains vs. the susceptible MHco3(ISE) strain, and *lgc-3* and *lgc-33* which are highly differentially expressed in the resistant MHco10(CAVR) vs. MHco3(ISE). These genes offer a potential starting point for functional investigations into their potential roles in ivermectin resistance.

## Session 5: Diagnosis - 1: Mixed Species

### 26

**Advancements in marine parasitology: optimization of diagnostic techniques and development of educational tools**

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Recent studies have sought to optimize the fecal flotation procedure to improve the detection of helminth eggs in domestic species. It is unclear, however, whether these efforts in optimization are applicable to parasite species of marine origin. Since parasitism is a common comorbidity in stranded pinnipeds, verification of these diagnostic procedures is clinically important. We hypothesized the helminth eggs of pinnipeds would have different specific gravities (SpG) than those of terrestrial species. Fecal samples were collected from 27 stranded pinnipeds temporarily housed at The Marine Mammal Center for rehabilitation. Flotations were performed on 1 gram samples. Sugar-gradient modified centrifugation flotations were conducted on ten samples to determine the SpG of helminth eggs. Trematode, ascarid, and cestode eggs were detected in 14/27 (52%), 10/27 (37%), and 4/27 (15%) individuals, respectively. Trematode eggs per gram (EPG) ranged from 1 to too numerous to count (TNTC), whereas ascarid counts ranged from 3 -482 EPG. While ascarid eggs had a SpG of 1.00 - 1.15, the ascarid eggs from 2/7 (29%) individuals had a broader range of SpG. Trematode eggs had a high SpG of 1.15 - 1.27, and 4/9 (44%) individuals had a SpG ranging from 1.05 - 1.27. The SpG of trematodes and ascarids was similar to that seen in terrestrial hosts. A series of educational tools were created to visually represent results and promote education in marine parasitology. Intended for broad audiences and targeting multiple age cohorts, these tools incorporate the use of web-based story maps, digital timelines and images, instructional videos and multi-plane images of eggs. These resources will benefit students, volunteers, technical staff, and the medical professionals that work with these animals.

## 27

**Evaluation of the card agglutination test (CATT/ *T. evansi*) for detection of *Trypanosoma evansi* infection in donkeys in Egypt.**

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A card agglutination test (CATT/ *T. evansi*) was evaluated for detection of antibodies against *Trypanosoma evansi* (*T. evansi*) in experimentally and naturally infected donkeys. Six donkeys (one year old) free from *T. evansi* after parasitological (buffy coat technique, mouse inoculation) and CATT/ *T. evansi* were assigned into experimental (no. 1, 2, 3, 4 and 5) and control (no.6) groups. The *T. evansi* strain was isolated from naturally infected horse from Egypt. Five donkeys (1, 2, 3, 4 and 5) were each inoculated intravenously with 350,000, 500,000, 250,000, 50,000 and 100,000 trypanosomes / animal, respectively. Two blood samples (heparinized and plain blood) were taken from each donkey every 4 days until the end of the experiment (50 days post- inoculation (DPI)). Body temperature (BT) and blood smears were obtained daily from each donkey. Parasitological examination of the experimental donkeys revealed a prepatent period of *T. evansi* 1-4 DPI. The *T. evansi* was diagnosed from donkey no. 1, 2, 3, 4 and 5 until 50, 28, 8, 40 and 36 DPI respectively. Donkey no.1 and no.6 survived until the end of the experiment. Seroconversion occurred on day 12 (end- titer 1:32), 8 (1:8), 4 (1:8), 16 (1:4) in donkeys no. 1, 2, 4, and 5 respectively. The peaks of high temperature and the clinical symptoms were reported among the inoculated donkeys. Donkey no.6 (control) was negative parasitologically and serologically with normal body temperature during the period of the experiment. The 416 donkeys from different governorates of Egypt were negative parasitologically while serological examination revealed 63 (15.12%) donkeys were positive at dilution of 1:4 or more. CATT/*T. evansi* was compared with PCR for diagnosis of *T. evansi* among 26 parasitologically negative donkeys. Serologically, 9 donkeys were positive and 9 doubtful while PCR showed 11 positive.

## 28

**Serological diagnosis of *Parelaphostrongylus tenuis* infection**

Jessie Richards*, Manasi Balachandran, Richard Gerhold, Stephen Kania. University of Tennessee, Knoxville, TN

*Parelaphostrongylus tenuis* is a parasitic nematode which utilizes white-tailed deer as the definitive host. The parasites invade the central nervous system (CNS) of aberrant hosts causing both mechanical and inflammatory damage. Techniques currently available for diagnosis include necropsy to detect nematodes or eggs in the brain and/or spinal cord, PCR of CNS tissue, or examining the cytology of cerebral spinal fluid. The goal of the present research was to develop an assay to accurately and rapidly diagnose *P. tenuis* infection antemortem or from banked serum. A gene encoding a *P.tenuis* aspartyl protease inhibitor, Pt-API-1, was inserted into an expression plasmid and propagated in *E. coli*. The recombinant protein was affinity purified, separated on SDS-PAGE gels and transferred to nitrocellulose. Western blots were utilized to identify anti-*P.tenuis* antibody present in blood, serum and CSF using sera from known positive and negative animals. Enzyme conjugated anti-cervid antibody produced in chickens was used to detect serologically positive elk, moose and deer. After Western blots were confirmed to be effective diagnostics, enzyme-linked immunosorbent assays (ELISAs) were used to test overlapping 10-mer synthetic peptides for the development of a more cost effective, less labor intensive test. However, due to inconsistent results and cross reactivity with other similar organisms, we have moved our attention to a full genomic analysis of *P. tenuis* to further distinguish a more definitive

antigen.This effort is ongoing but is expected to identify epitopes that are unique to *P.tenuis* and serve as a useful diagnostic assay.

## 29

**A niche and lonely endeavor: investigating the cestodes of wild turkeys (*Meleagris gallopavo silvestris*) from Tennessee.**

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Cestodes are common parasites of birds, whichhave the most diverse cestode fauna of any vertebrate group. However, these parasites are a neglected aspect of avian health, and there is limited knowledge on wild turkey cestodes, their potential disease implications, and their geographic distribution. Recent reports of wild turkey population declinein middle Tennessee have sparked renewed disease investigation in turkey parasites and diseases. During 2014 and 2015, in conjunction with Tennessee Wildlife Resources Agency, hunter-harvested male turkeys in middle Tennessee were necropsied and gastrointestinal tracts collected. Sixty-three fresh gastrointestinal tracts were examined for adult cestodes and collected in 70% ethanol. Of the 63 birds, 60 turkeys contained cestodes in their gastrointestinal tracts. Cestodes were morphologically identified to lowest taxonomic order possible. *Raillietina* (*Raillietina*) spp. and *Metroliashes lucida* were identified and equally represented in our sample population. To further classify the cestode species present, DNA amplification by polymerase chain reaction followed by DNA sequencing of cytochrome c oxidase I (CO1) was performed on high quality samples (n=19). Preliminary DNA sequencing results strongly suggest *Raillietina* (*Raillietina*) spp. and *Metroliashes* sp. are present and efforts to finalize molecular results are ongoing. Voucher samples will be housed in the Smithsonian's National Museum of Natural History and genetic sequences will be deposited in GenBank. The integration of molecular and morphological identification of the avian cestodes will be a foundation for future wild turkey and avian cestode investigations.

## 30

**The value of PCR in the diagnosis of canine giardiasis**

Meriam Saleh*, Michael Leib, Anne Zajac. Virginia Tech, Blacksburg, VA

*Giardia duodenalis* is a common cause of diarrhea in dogs. Most infections are subclinical but can cause acute diarrhea and weight loss. Historically, infections were diagnosed microscopically by observing trophozoites in a direct fecal smear or cysts in a centrifugal fecal flotation test. These techniques provide limited sensitivity because trophozoites are only found occasionally in diarrheic samples, and cysts are shed intermittently. To combat these difficulties, fecal antigen tests that detect cyst antigen have been developed. Currently, a direct smear and centrifugal fecal flotation with a sensitive and specific fecal antigen test are recommended for diagnosis. Commercial labs offer PCR to diagnose *Giardia*. However there have been no direct comparisons of PCR to conventional microscopic techniques with an immunoassay. The objective of this study was to compare diagnostic techniques to determine whether PCR significantly improved *Giardia* detection. Conventional and real time PCR assays targeting the ssurRNA gene were evaluated. Diarrheic fecal samples were collected from dogs at local clinics and animal shelters and tested for *Giardia* with centrifugal zinc sulfate fecal flotations, a commercial immunoassay, and both PCR assays. Sensitivity and specificity of each PCR assay was determined by comparison to the recommended method of *Giardia* diagnosis (microscopy and immunoassay) and

agreement was measured using Cohen's kappa statistic. The real time PCR assay amplified a ~62bp gene fragment and was very sensitive (100%), but not very specific (11%) and had poor agreement with the recommended tests. Conventional PCR amplified a larger ~292bp fragment, was moderately sensitive (42%) with high specificity (93%) as well as fair agreement with the recommended diagnostic tests. This data indicates that agreement between PCR and microscopy and immunoassay varies depending on the molecular parameters and size of the DNA target and underscores the complexity of test evaluation and molecular diagnostics for *Giardia.*

## 31

**Efficacy of the mini-FLOTAC, in the diagnosis of canine *Giardia* infection**

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The mini-FLOTAC is a new diagnostic procedure gaining popularity for the microscopic detection of fecal parasite eggs and cysts. While its efficacy for diagnosing *Giardia duodenalis* infections in humans has been studied, there is less information about its efficacy in recovering canine *Giardia* cysts. Zinc sulfate flotation solution (33%) used in the centrifugal fecal flotation test appears to be the most effective microscopic procedure for detecting *G. duodenalis* cysts in veterinary clinical practice. However, many practitioners continue to use passive fecal flotation procedures and zinc sulfate solution is not highly effective in that procedure. The purpose of this study was to examine whether use of the mini-FLOTAC with zinc sulfate flotation solution would offer an improvement in sensitivity over passive flotation for the detection of *Giardia*. Therefore, results of zinc sulfate centrifugal fecal flotation were compared to mini-FLOTAC and passive fecal flotation (10 minute incubation) procedures. Canine fecal samples were collected from animal shelters. Samples were well mixed and three 2-gram aliquots of each sample were examined by centrifugal and passive flotation and mini-FLOTAC using 33% zinc sulfate flotation solution. Test results were recorded as positive or negative for all parasites seen. Sensitivities and specificities were compared and McNemar's test for significance of differences was determined. As expected, passive flotation was least effective in identifying samples positive for all parasites, including *Giardia*, while results of centrifugal flotation and mini-FLOTAC were more similar overall.

# Session 6: Epidemiology - 1: Protozoa

## 32

***Encephalitozoon cuniculi* survey in a dog breeding kennel**

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The intracellular eukaryotic parasite, *Encephalitozoon cuniculi* (Phylum Microsporidia) is an under-recognized zoonotic pathogen in dogs. Rapidly fatal encephalitis is the most common presentation in puppies, and chronic progressive nephritis has been reported in adult dogs. Routes of transmission include transplacental or ingestion of environmentally resistant spores that are shed in urine or feces. Little information is available regarding asymptomatic carriers that can pass the parasite vertically or can act as reservoirs for environmental contamination by shedding infective spores. The owner of a breeding kennel of Boston terrier dogs requested diagnostic support after receiving a post-mortem histopathologic diagnosis of fatal encephalitozoonsis in several newborn puppies. The referring DVM

collected and submitted blood (n = 53) and urine (n = 43) from animals in the kennel for serologic testing and microscopic evaluation of urine sediment for *E. cuniculi* spores. The kennel owner provided dog ages, gender and pedigree information for evaluation of transmission patterns. Twenty-nine dogs were seronegative, 21 dogs (40%) were seropositive, and results for 3 dogs were equivocal. Seventeen of 24 (71%) females and 4 of 29 (14%) males were positive. Microsporidial spores were detected in 6 of 43 (14%) of urine samples by microscopy of Calcofluor M2R-stained urine sediment. Serologically positive and serologically negative bitches had both seropositive and seronegative puppies suggesting parasite transmission occurred through ingestion of spores from the environment. The frequencyof transplacental transmission could not be determined using these data. Serologic data indicate that exposure to *E. cuniculi* was common in this population of dogs. Unrecognized asymptomatic infections, as indicated by parasite spore shedding in the urine ofclinically normal dogs, are a source of environmental contamination.

## 33

### *Toxoplasma* and *Sarcocystis* spp. cysts found in raw meat-based diets for cats and dogs

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Feeding raw meat-based diets (RMBD) to companion animals has become increasingly popular. Since these diets may be contaminated with pathogens, they may pose a risk to both animal and human health. We tested the presence of *Toxoplasma gondii* and *Sarcocystis* spp. in thirty-five Dutch commercial frozen raw meat-based diets from eight different brands. *S. cruzi* was found in four products (11%) and *S. tenella* in another four products (11%). Zoonotic *S. hominis* or *S. suihominis* were not present. In two products (6%) *T. gondii* was found.

Dogs infected with *Sarcocystis* spp. shed infective sporocysts in their feces for several months. *S. cruzi* produce microscopic cysts, principally in myocardium, and can affect 100% of some cattle populations. It may cause acute disease in calves, eosinophilic myositis in cattle, and abortions, stillbirths, and deaths in pregnant cows. Bovine eosinophilic myositis is primarily responsible for cattle condemnation. Inflammation, hepatitis and myocarditis are the main lesions of acute and subacute ovine sarcocystosis. Intrauterine *Toxoplasma* infections may cause retinochoroiditis, encephalomyelitis and hydrocephalus or microcephaly in newborns.

The results of this study demonstrate the presence and potential zoonotic character of pathogens in RMBDs. These diets should therefore not be neglected as a possible source of parasitic infections in both humans and production animals. Most of the RMBDs are sold frozen and tissue cysts will be inactivated. If raw pet food, however, is purchased fresh and prepared at home without freezing, there will be a potential risk of parasitic infections in pet animals, which can result in shedding of oocysts in the environment, thereby leading to potential additional exposure to humans and livestock. Pet owners should be informed about the risks associated with feeding their animals RMBDs.

## 34

**Investigation of the Potential Transmission of *Histomonas meleagridis* from Poultry Litter to Wild Turkeys**

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Two separate investigations were performed to establish data on the health of wild turkeys (*Meleagris gallopavo*) and the potential of *Histomonas meleagridis* transmission from commercial poultry litter to wild turkeys in a three county area in middle Tennessee where wild turkey numbers are perceived to be lower. The first investigation examined hunter-killed turkeys for lesions in conjunction with serological and molecular testing. A total of 218 wild turkeys were examined. Carcasses were examined for gross and microscopic lesions and sera Important histological findings of hunter-killed turkeys from 2014 included enteritis, typhlitis (cecal inflammation) and various granulomas within organs. Histological lesions from 2015 hunter-killed turkeys included moderate to severe typhlitis in 75 (67%) of turkeys. Polymerase Chain Reaction (PCR) testing to amplify *Histomonas meleagridis* DNA followed by nucleotide sequencing was performed on cecal tissue from all turkeys with histological evidence of cecal lesions. The PCR and sequence results indicated that three birds have evidence of *H. meleagridis* DNA. In the second experimental infection bioassay trial involving poultry litter from poultry facility in the middle Tennessee area, one of 24 experimental wild turkeys was euthanized on day 13 due to severe lethargy. Necropsy findings disclosed liver and cecal lesions consistent with *H. meleagridis* infection, which was confirmed by histological, parasite culture, and PCR testing. A second experimental turkey with cecal lesions was PCR and sequence positive for *H. meleagridis*. Collectively, our results suggest that *H. meleagridis* may be associated with poultry litter and may be a cause for concern for wild turkeys in this region; however, further research is needed before this connection can be confirmed.

## 35

**Serologic detection of *Trypanosoma cruzi* infections in free-roaming feral and stray cats in Oklahoma**

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*Trypanosoma cruzi* is the arthropod-borne protozoan that is the causative agent of acute and chronic Chagas' disease in dogs and humans in the Americas. Transmission to vertebrates is primarily stercorarian from the triatomine host during or after blood feeding, but transplacental, blood-borne, and oral transmission routes are also reported. Over 100 mammalian species are documented hosts of *Trypansoma cruzi*, 24 of these in North America. In many endemic areas, domestic dogs (*Canis familiaris*) are considered the prominent reservoir host infecting feeding triatomines, and infection prevalence in domestic dog populations may reflect the risk of human disease in these areas. Regional survey studies in Texas have documented *T. cruzi* infections in triatomines, indigenous wildlife, and domestic dogs, indicating that the parasite is actively cycling in nature in North America. Infected domestic dogs have been identified throughout the southern United States, but their role in maintaining enzootic cycles in nature is not entirely understood. Reports of *T. cruzi* infections in domestic cats in general are historically more limited, but cats are also reported potential reservoirs of *T. cruzi* in Central and South America. Although wild felids in North America are documented natural hosts of *T. cruzi*, no survey data evaluating infections in domestic cats have been reported. To gain a better understanding of the prevalence of *T. cruzi* infections in domestic cats in the southern United States, free-range stray and feral cats from Oklahoma were tested for reactive antibodies using the immunochromatographic Chagas

STAT-PAK® Assay. Out of 396 samples screened, 18 cats were seropositive, or a total of 4.5%. Whole blood samples from seropositive cats were extracted for total DNA and tested by separate PCR assays amplifying an 188-base pair segment of a repetitive nuclear DNA sequence and a size variable domain of the 18s rRNA sequence to identify circulating parasite.

## 36

**Dog kennels as a nidus of infection: triatomine vector activity, *Trypanosoma cruzi* infection dynamics and Chagas disease cardiomyopathy in a central Texas dog kennel**

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*Trypanosoma cruzi* causes Chagas disease in humans and dogs throughout the Americas, and disease dynamics across the southern US remain poorly understood. Knowledge of vector activity, variation in *T. cruzi* circulation in dogs over time, and pathogenic outcome would provide important information for veterinary and human health. We conducted a multi-faceted study in an outdoor kennel of Belgian Malinois and Labrador retriever dogs in central Texas. We used time-lapse photography to document nocturnal activity of triatomine vectors, conducted repeated cross-sectional study of *T. cruzi* infection in dogs, and opportunistically necropsied two infected dogs. Triatomines were active throughout the night, with the greatest number of triatomines in early morning (0400-0600). Interestingly, some triatomines sat on the kennel walls for several hours without making apparent dog contact. Over 85% (n=14) of *Triatoma gerstaeckeri* and *T. sanguisuga* collected in the kennel were infected with *T. cruzi* discrete typing units (DTU) TcI and/or TcIV, and (based on PCR) several had fed on dogs. In October 2016, 73.6% of dogs (n=53) were seropositive on e2 tests (IFA, Chagas Stat-Pak, and/or Chagas Detect Plus). Additionally, 24.5% of dogs had PCR-positive blood, with DTU TcI or TcIV. In April 2017, 54.8% of dogs (n=42) were seropositive and, according to IFA results, none of 36 re-sampled dogs had changed serostatus. Eleven dogs (21.4%) were PCR-positive in April; of these, six had been positive in October and three converted from negative to positive. Two dogs had converted from PCR-positive to PCR-negative. These data show infected dogs may have variation in apparent presence of circulating *T. cruzi* DNA. Opportunistic necropsies of two seropositive dogs with suggestive clinical signs revealed chronic Chagas myocarditis in one, and unrelated lung adenocarcinoma in the other. Canine kennels serve as a nidus for *T. cruzi* transmission.

## 37

**Infection of *Babesia conradae* in hunting greyhounds from Oklahoma**

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*Babesia conradae* is a small, intraerythrocytic piroplasm found in dogs from southern California. In domestic dogs, *B. conradae* infection causes lethargy and hemolytic anemia. In March 2014 a greyhound used to hunt coyotes in Oklahoma presented with lethargy and pale mucous membranes. Evaluation of stained blood film revealed small piroplasms in red blood cells. Subsequent DNA extraction of whole blood, PCR amplification using piroplasm-specific primers, and DNA sequencing confirmed infection by *B. conradae*. The index case dog was euthanized by the owner due to deteriorating condition. Follow-up evaluation of the majority of dogs in the owner's kennel revealed that 3 of 6 (50%) greyhounds and 0 of 4 (0%) walker hounds were PCR positive for infection with *B.*

*conradae*. No dogs were known to have travel histories west of Oklahoma. Two of the greyhounds subclinically infected with *B. conradae* were treated with an 8 day course of azithromycin (10 mg/kg [4.5 mg/lb], PO, q 24 h) plus atovaquone (13.3 mg/kg [6 mg/lb], PO, q 8 h). The third *B. conradae*-infected dog was sold and lost to follow-up. Approximately one month after completion of azithromycin and atovaquone treatment, both dogs were PCR negative for infection with *B. conradae*. Subsequent PCR analysis of 16 bloods samples from hunting greyhounds housed in a second kennel in central Oklahoma demonstrated infection of *B. conradae* in 4 (25%) dogs and *Hepatozoon canis* in 1 (6%) dogs. To the authors' knowledge, this is the first report of *B. conradae* in dogs outside of California.

## Session 7: Molecular and Biochemical - 2

### 38

**Improved sampling for and determination of seasonal incidence of dog heartworm-infected mosquitoes**

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The causative agent of dog heartworm disease, infection with *Dirofilaria immitis,* is common, annually impacting 750,000 dogs in the United States. Extensive research has improved our understanding of *D. immitis* infection in canines, but the details of its epidemiology and the vector capacity of mosquito species is not well known. The majority of published research has focused only on the host-seeking subset of wild mosquito populations, many of which have never blood-fed on a host and thus, cannot harbor *D. immitis*. Our project examined seasonality of infections in a broad range of mosquito groups including: unfed, host-seeking, previously fed, and gravid types, using mosquito field collections from four residences and three dog kennels spanning two years. Through this project, we developed and will present the results of a multiplex qPCR that targeted two regions of COI with detection exceeding one nematode in a pool of 100 mosquitoes.

### 39

**Molecular evidence for black flies (*Simulium* spp.) as vectors of an uncharacterized *Onchocerca* species**

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The role of different black fly (Diptera; Simuliidae) species as vectors of filarial nematodes of the genus *Onchocerca* (Nematoda; Onchocercidae) infecting wild ungulates in North America is scarcely known. Moreover, there is recent evidence for the existence of a richer *Onchocerca* biodiversity in the continent. To understand the vectors of species of *Onchocerca* in the Los Angeles County, southern California, USA, 1056 female black flies was collected from 39 sites using EVS mosquito traps from March to November 2015. Black flies were morphologically identified to species complex: *Simulium tescorum* (356), *Simulium vittatum* s.l. (683), and additional 17 specimens were not assessed morphologically. Specimens were individually processed for DNA extraction. A nested PCR targeting the cytochrome oxidase subunit 1 (COI) gene of filarial nematodes was performed. Products of PCR-positive samples

were sequenced. Phylogenetic analyses were performed in MEGA 7, comparing sequences with other *Onchocerca* species. *Onchocerca* sequences were detected in 4.8% (n=17) *S. tescorum* samples, and only one *S. vittatum* (0.15%), from 6 sites in 3 cities (Azusa, Glendora and San Dimas). COI sequences were reciprocally monophyletic (99.5-100% pairwise identity; PI), and most similar to *Onchocerca gutturosa* (93.9-94.9% PI) and not to *Onchocerca cervipedis* (89.5-90.2% PI), as hypothesized. PCR targeting the cytochrome B of vertebrate species to assess from which hosts the black flies acquired a blood meal detected DNA of *Odocoileus* sp., the natural host of *O. cervipedis* and of other *Onchocerca* species in Eastern USA, whose taxonomic characterization is pending. *Simulium tribulatum*, a species in the *S. vittatum* complex, is the putative vector of the zoonotic *Onchocerca lupi* in the same region.This is the first evidence of *S. tescorum* and *S. vittatum* s.l. as putative vectors ofan uncharacterized *Onchocerca* species.

## 40

**Inherent Oxidative Stress in Lewis Rat Mediates Resistance to Toxoplasmosis**

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The course of *Toxoplasma gondii* infection in rats closely resembles that in livestock and humans. However, compared to the Brown Norway (BN) rat, the Lewis (LEW) rat is extremely resistant to *T. gondii* infection. Thus, we performed RNA sequencing analysis of the LEW versus BN rat, with or without *T. gondii* infection, in order to unravel molecular factors directing the robust and rapid early *T. gondii*-killing mechanism in the LEW rat. We found that, compared to the uninfected BN rat, the uninfected LEW rat has inherently higher transcript levels of Cytochrome enzymes [Cyp2d3, Cyp2d5 and Cybrd1 that catalyze generation of reactive oxygen species (ROS)], with concomitant higher levels of ROS. Interestingly, despite having higher levels of ROS, the LEW rat had lower transcript levels for antioxidant enzymes (lactoperoxidase, microsomal glutathione S-transferase 2 and 3, glutathione S-transferase peroxidase kappa 1 and glutathione peroxidase) than the BN rat, suggesting that the LEW rat maintains cellular oxidative stress that it tolerates. Corroboratively, we found that scavenging of superoxide anion by MnTBAP [Mn (III) tetrakis (4-benzoic acid) porphyrin] decreased the refractoriness of LEW rat cells to *T. gondii* infection, resulting in proliferation of parasites in LEW cells which, in turn, led to augmented apoptosis in the infected cells. Together, our results indicate that the LEW rat maintains inherent cellular oxidative stress that contributes to rapid killing of invading *T. gondii,* and thus unveil new avenues for developing therapeutic agents targeting induction of host cell oxidative stress as a mechanism for killing *T. gondii*.

## 41

**A unique plant-like nuclear kinase plays an essential role in acute toxoplasmosis**

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In *Toxoplasma*, kinases have been shown to play key roles in parasite motility, invasion, replication, egress and survival within the host. An unexplored set of kinases in *Toxoplasma* are the Tyrosine Kinase Like (TKL) family of proteins. Bioinformatics analysis of the *Toxoplasma* genome identified eight genes annotated as TKLs, which we have named numerically according to their predicted fitness scores. Endogenous tagging of the six TKLs that are important for tachyzoite fitness showed that these proteins localize to various compartments in the parasite including the nucleus (TgTKL1 & TgTKL2), cytosol (TgTKL3 & TgTKL4) IMC (TgTKL5) and Golgi (TgTKL6). We chose to first characterize the nuclear localized TgTKL1, as it is unique among the TgTKL family in that it contains an Enhanced Drug

Resistance 1 (EDR1) domain that is found only in plants and protozoa. TgTKL1 knock-out parasites displayed significant defects in the progression through the lytic cycle and in the attachment step of host cell invasion, which was restored upon TgTKL1 complementation. Additional analyses showed that microneme secretion and processing is impaired in parasites lacking TgTKL1. Transcriptomics analysis revealed that over 300 genes of diverse functions were differentially expressed in TgTKL1 KO parasites, with numerous genes implicated in host cell invasion process among the most significantly down-regulated. Significantly, mice inoculated intraperitoneally with TgTKL1 KO parasites all survived the infection, suggesting that TgTKL1 plays an essential role in acute toxoplasmosis. Together, these findings suggest that TgTKL1 mediates a signaling pathway that regulates the expression of factors required for parasite virulence, underscoring the potential of this plant-like kinase as a novel therapeutic target.

## 42

**Characterization of a ATP binding cassette transporter from *Toxocara canis***

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*Toxocara canis* is a cosmopolitan ascarid nematode of dogs. Adults are found in puppies following a complex migration through the liver and lungs. In mature dogs, larval migration results in the formation of somatic larval stages that tolerate macrocyclic lactones used to kill adult worms. Somatic larval burdens in bitches results in transplacental and transmammary transmission of larvae to subsequent generations of puppies. Therefore, addressing the problem of somatic *Toxocara canis* larvae is crucial for controlling this parasite of veterinary and human medical importance. We hypothesized that larval drug tolerance is mediated by the ATP binding cassette transporter family which promotes resistance in other nematode parasites. Our investigation revealed an ABCB1 gene that is expressed in adult and larval *Toxocara canis*. Heterologous expression assays demonstrated the relevance of this protein to macrocyclic lactone efflux and may be used as a model to discover nematode-specific ABC transport inhibitors.

# Session 8: Case Reports and Novel Findings

## 43

**Case Report: Uncommon cause of dermatitis in a dog – *Pelodera* (syn. *Rhabditis*) *strongyloides* infestation**

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*Pelodera* (*Rhabditis*) *strongyloides* is a saprophagous free-living nematode found in decaying organic matter or moist soil. Under suitable conditions, the nematode may parasitize living animals, resulting in a pruritic, hyperemic dermatitis. This is a case report of dermatitis in a dog caused by rare *P. strongyloides* infestation.

Approximately 1-year-old, intact female, Australian Shepherd mix was presented to Marlow Veterinary Clinic in Marlow, Oklahoma with a history of alopecia, hyperemia, and pruritus on the ventral abdomen, lateral side of hind legs, and upper lips for a month. The dog was kept outside as a farm dog with some goats; straw was used for bedding. According to the owner, all clinical signs began showing up after the

dog gave birth to a litter of puppies. Skin scraping was performed by rDVM and revealed a moderate number of motile nematode larvae. Samples were forwarded to the parasitology diagnostic laboratory at Oklahoma Animal Disease Diagnostic Laboratory (OADDL) for further evaluation.

The nematode larvae were approximately 500 µm in length with a simple straight tail. A rhabditiform esophagus was observed although it was challenging to find since it was less prominent than that of *Strongyloides* spp. larvae. The larvae were placed on nutrient agar plates and kept at room temperature for 48-72 hours to allow larvae grow to adults. A moderate number of short and stout adults with characteristic rhabditiform esophagi and 6 distinct lips was observed. Males were approximately 1100 µm in length with Y-shaped spicules and well-defined copulatory bursa, whereas females were approximately 1350 µm in length with conical tail with a small terminal spike. Based on the characteristic morphologic features, the nematode was identified as *P. strongyloides*. The dog was treated with topical moxidectin/imidacloprid, and her bedding area was cleaned. Histopathologyand treatment outcome will be discussed in the presentation.

## 44

**Case report: Fatal *Strongyloides stercoralis* infection in a 12-week-old puppy in Oklahoma, USA**

Yoko Nagamori*, Alexandra Dieterly. Oklahoma State University, Stillwater, OK

*Strongyloides stercoralis* is a nematode parasite of canids and humans that is distributed worldwide. Most cases are usually asymptomatic; however, severe infection can cause diarrhea and respiratory signs. Although fatal strongyloidiasis has been reported in humans, reports of fatal canine cases were not found. This is a case report of a rare, overwhelming *S. stercoralis* infection resulting in the death of a young puppy.

*Strongyloides stercoralis* was diagnosed post-mortem in a 12-week-old, intact female, Teacup Poodle with a history of continuous vomiting for 24 hours. On gross examination, the animal was in slightly thin body condition. The lungs were slightly overinflated, failed to collapse when opening the thorax, and contained numerous pinpoint multifocal dark red foci areas of discoloration. The diaphragmatic capsular surface of the liver contained 2 x 3 mm, round tan foci. On fecal direct smear, high numbers of approximately 300–350 um nematode larvae with a rhabditiform esophagus, genital primordium, and simple straight tail, consistent with first stage *S. stercoralis* larvae, were observed. A large number of morphologically similar larvae were recovered from the lungs using Baermann's technique. Intestinal contents were cultivated with vermiculite for 24–36 hours, and filariform larvae with bipartate tails and elongated esophagi were recovered, confirming *S. stercoralis* infection. On histologic examination, numerous nematode larvae were present within the intestinal lumen and mucosa, surrounded by inflammation. The interstitium and alveolar spaces in the lungs contained a moderate amount of hemorrhage with a few nematode larvae, attributed to acute parasitic migration. The lesions in the liver were consistent with multifocal areas of mild inflammation, also suggestive of parasitic larval migration. The severe *S. stercoralis* infection and subsequent pulmonary migration and gastroenteritis were considered to be the primary cause of death in this puppy.

## 45

**Dermal microfilariae of *Cercopithifilaria bainae* in a dog in south Florida: First report in the United States**

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*Cercopithifilaria bainae* is a filarioid nematode first described in 1984 in a dog in Brazil. The adults are found in the subcutaneous tissues, and microfilariae in the dermis. This nematode has been associated with erythematous dermatitis in dogs and previously reported in Europe and Central and South America. *Rhipicephalus sanguineus* is the proposed vector. In March 2017, a 1 year old Labradoodle from Sarasota, Florida, with no known travel history outside of Florida or the United States, was presented to the University of Florida, College of Veterinary Medicine with a one month history of circular erythematous plaques on the cranium and ulcers on the medial canthi that had been nonresponsive to antibiotics. Histopathologic evaluation of multiple punch biopsies revealed an eosinophilic to lymphohistiocytic perivascular dermatitis with multiple microgranulomas. Rare extracellular 10-15 microns in diameter microfilariae bound by a less than 1 micron thick lightly eosinophilic cuticle were found within microgranulomas. Microfilariae were filled with irregularly round basophilic nuclei, 1-2 microns in diameter. Heartworm antigen tests and Modified Knott's test were negative for *Dirofilaria immitis* antigen and *D. immitis* and *Acanthocheilonema reconditum* microfilariae, respectively. Additionally, fecal analysis was negative for intestinal parasites and there were no reported abnormalities on cell blood counts, serum biochemistry, and urinalysis. A macerated 6mm tissue biopsy revealed several microfilariae morphologically consistent with *C. bainae.* Microfilariae were 187-193 microns in length, transversely striated, had a rounded head and many nuclei seen throughout the body. The excretory cell was visible on some specimens. PCR and sequencing of the *cox*1 and 18S rRNA genes confirmed the identity as *C. bainae.* The dog has been treated with a commercial spot-on containing imidacloprid and moxidectin. This is the first known report of *C. bainae* recovered from any species in the United States.

## 46

**Associations between fecal egg count, presence of *Strongylus vulgaris*, and body score of feral horses on Fort Polk, Louisiana**

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Approximately 700 feral horses, dubbed "trespass horses" by the United States Army, occupy Fort Polk, Louisiana and the surrounding Kisatchie National Forest. These horses are considered a nuisance and hazard, and the military is seeking to remove the horses via adoption. The aim of this research was to determine the fecal egg count (FEC), body condition score (BCS), and *Strongylus vulgaris* presence on these never-before-studied horses before they are removed. The feral horse data was compared to results from domestic horses living on a single farm in the same area. A modified McMaster FEC, Henneke body scoring via photography, and traditional PCR were used to gather data on 10 domestic horses in September 2016 and 28 feral horses in October 2016. A statistically significant difference ($p$=0.004) was found in FEC between domestic and feral horses, and 69.2% of feral horses were positive for *S. vulgaris* versus zero domestic horses. Domestic horses had a mean FEC of 896 EPG and ranged from 0 EPG to 1213 EPG, whereas feral horses had a mean FEC of 1270 EPG and ranged from 0 EPG to 3713 EPG. Mean BCS for feral and domestic horses were 5.0 and 5.2 respectively. Additionally, no association was

found between FEC and BCS for domestic ($p$=0.213) or feral ($p$=0.099) horses, and no association was found between FEC and *S. vulgaris* presence ($p$=0.21) or BCS and *S. vulgaris* presence ($p$=0.52). This research gives insight into *S. vulgaris* and strongyle prevalence in a previously unstudied group of horses and indicates a need for anthelmintic treatment and monitoring of the feral horses once they are adopted.

## 47

**Experimental transmission of an *Ehrlichia* spp. following exposure to *Amblyomma americanum***

Brian Herrin*, Samantha Hancock, Todd Holbrook, Susan Little. Oklahoma State University- CVHS, Stillwater, OK

Tick infestations are a commonly recognized problem in horses, with *Amblyomma americanum* the predominant tick found on horses in the southeastern and southcentral United States. While there is currently no description of a true, equine-specific *Ehrlichia* spp., horses within the natural range of *A. americanum* have been shown to have antibodies reactive to an ehrlichial agent. Therefore, to determine the vector potential of *A. americanum* as a source of ehrlichial infection in horses, describe which *Ehrlichia* spp. may infect horses, and document any clinical manifestations of infection, 5 naïve horses were each infested with 100 (50F:50M) wild-caught ticks per infestation on 5 separate days (500 ticks total). Horses were monitored daily for signs of clinical disease, and thrice-weekly blood draws were collected for polymerase chain reaction (PCR), serology, and complete blood count/chemistry. Average tick attachment peaked on Day 21 at 80 ticks/horse. At day 28, one horse had a prolonged clotting time after jugular venipuncture, but follow-up blood work revealed no abnormalities. No other clinical signs of infection or blood work abnormalities were consistently noted in any horse. By day 21 all 5 horses were seropositive for antibodies reactive to *E. chaffeensis* by indirect immunoflourescent assay (IFA), while only one horse tested positive by enzyme-linked immunosorbent assay (ELISA). Specific PCRfor *E. chaffeensis, E. ewingii,* or Panola Mountain *Ehrlichia* spp. failed to amplify DNA from whole blood or buffy coat at any time point. This study shows that horses exposed to *A. americanum* develop antibodies to *Ehrlichia* spp. and may remain transiently infected; however, further studies are required to fully identify which ehrlichial agents can infect horses and the clinical significance associated with those infections.

# Session 9: Parasite Control - 2: Natural Approaches

## 48

**Impact of a refugia-based strategy in stocker cattle on species diversity, pasture contamination, and development of resistance**

Kelsey Paras[1], Amelia Woolums[2], Kris Hubbard[2], Liesel Schneider[2], Brandi Karisch[2], John Blanton[2], Dave Smith[2], Bill Epperson[2], Bob Storey[1], Ray Kaplan*[1]. [1]University of Georgia, Athens, GA, [2]Mississippi State University, Starkville, MS

Anthelmintic resistance in gastrointestinal nematodes of cattle is becoming increasingly prevalent worldwide. Studies in sheep clearly demonstrate that refugia-based strategies reduce the rate with which anthelmintic resistance develops. In this study we tested a selective non-treatment refugia-based strategy in cattle. Mixed stocker calves (184-334kgs) were purchased at sale barns in the southern USA and allowed to contaminate a newly sown wheat/rye grass pasture. Stockers were then allocated randomly into three treatment groups; 100% treated with Dectomax® (doramectin), 100% treated with

LongRange® (eprinomectin), and 90% treated with LongRange® (eprinomectin), and moved onto three newly sown wheat/rye grass pastures for 112 days. Worm-free tracer calves (Group 1) grazed the original contaminated pasture for four weeks; half were then treated with LongRange® and half left untreated, followed by necropsy and worm recovery. After 112 days of grazing, stockers were removed and replaced with three sets of tracers (Group-2) and the same tracer protocol was repeated. Surprisingly, for both Group-1 and 2 tracers, there was no significant difference in *Ostertagia ostertagi* mucosal L4 numbers between treated and untreated calves (p=0.7, 0.88). In contrast, reduction of adult *O. ostertagi* in group 1 tracers was 99.6%, but decreased to 91.2% in group-2 tracers. Adult *Cooperia* spp. were reduced by 75.13% in group-1 tracers, whereas efficacy decreased in group-2 tracers to 64.6%, 28.9%, 42.2% for the Dectomax®, 100% LongRange®, 90% LongRange® groups, respectively. Though further statistical analyses are in progress, these efficacy data suggest that leaving 10% of calves untreated did not provide sufficient refugia to make an impact on development of resistance. However, the reduction in efficacy observed in group-2 compared to group-1 tracers suggests that a single anthelmintic treatment given to cattle placed onto clean pastures can rapidly select for resistance, emphasizing the important role that refugia play in limiting resistance development.

## 49

**Evaluation of a refugia-based strategy in pastured stocker cattle treated with LongRange®**

Kelsey Paras*[1], Amelia Woolums[2], Kris Hubbard[2], Liesel Schnieder[2], Brandi Karisch[2], John Blanton[2], Dave Smith[2], Bill Epperson[2], Bob Storey[1], Ray Kaplan[1]. [1]University of Georgia, Athens, GA, [2]Mississippi State University, Starkville, MS

Anthelmintic resistance in gastrointestinal nematodes (GIN) of cattle is becoming increasingly prevalent worldwide. Refugia-based strategies have proven effective in slowing the development of resistance in parasites of sheep, but few studies have examined this strategy in cattle. In this study, we examined the use of a selective non-treatment strategy in stocker cattle. 180 stocker calves ranging in weight from 184-334kg were allocated randomly into three treatment groups; 100% treated with Dectomax® (doramectin), 100% treated with LongRange® (eprinomectin), and 90% treated with LongRange® (refugia group). Following treatment, cattle were placed on newly sown wheat/rye grass pastures for 112 days. Cattle were weighed and fecal samples collected for egg counts and coprocultures at the time of treatment and then monthly for 4 months. After 112 days of grazing, there were no significant differences between the three treatment groups in total weight gain (p= 0.74), average daily gain (p=0.83), or in numbers of cases bovine respiratory disease (p=0.44). Mean FEC at treatment was 514 EPG, with *Cooperia, Haemonchus, Ostertagia,* and *Oesophagostomum* all observed on coprocultures. FEC reductions 28 days post-treatment were, 70.4%, 92.1%, 87.9% for Dectomax®, 100% LongRange®, and 90% LongRange® groups, respectively, with resistance only detected for *Cooperia*. By 112 days the EPG of all groups were low, averaging 12.8 across the three groups. No *Ostertagia* larvae were observed one month post-treatment, but were observed in coprocultures by the end of the study. Treating only 90% of the herd with LongRange® had minimal impact on parasitological parameters, and did not significantly affect group weight gain, suggesting that a selective non-treatment approach may be a sound approach for integrating a refugia-based strategy for parasite control in cattle.

## 50

**Effects of terminal sire breed on parasitism of crossbred market lambs in a hair sheep production system**

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Gastrointestinal nematodes (GIN) can have a significant impact on the performance of lambs in an extensive production system. To evaluate the effects of sire breed on GIN infection, Katahdin (KT, n = 4), Suffolk (SU, n = 3), and Texel (TX, n = 3) rams were randomly mated to KT ewes over two years at the Virginia Tech Southwest Agriculture Research and Extension Center. At weaning, lambs (n = 192) were moved to ungrazed fescue pasture and supplemented with a concentrate pellet for a 90-d grazing trial. BW, fecal egg count (FEC), FAMACHA score, and packed cell volume (PCV) were collected biweekly. Deworming occurred based on FAMACHA score e 3 with levamisole (8mg/kg) or moxidectin (0.2mg/kg). SAS (SAS Institute Inc., Cary, NC) was utilized for statistical analysis with Tukey's test for comparative means analysis. In both years, FEC and FAMACHA score varied over time ($P < 0.05$). In year 1 (Y1), KT-sired lambs had lower FAMACHA scores compared to SU- and TX-sired lambs (1.7 vs. 2.4 and 2.2, respectively; $P < 0.05$) and there was a tendency for KT-sired lambs to have lower FAMACHA scores compared to SU-sired lambs (1.4 vs. 1.6, $P = 0.053$) in year 2 (Y2). PCV varied over time ($P < 0.05$) with no breed effects. In Y1, a lower proportion of KT-sired lambs tended to required deworming compared to SU-sired lambs (65 vs. 90%, $P = 0.084$). In Y2, KT-sired lambs tended to require less deworming compared to SU- and TX-sired lambs (31 vs. 55%, $P = 0.06$; 31 vs. 50%, $P = 0.08$; respectively). In Y1, TX-sired lambs had greater ADG than KT-sired lambs (0.09 vs. 0.06 kg/d, $P < 0.05$). No ADG differences existed in Y2. While KT-sired lambs had enhanced resistance to GIN, TX-sired lambs may have growth advantages.

## 51

**The enemy of my enemy is my friend: using a soil bacterium to kill parasitic nematodes**

Yan Hu[1], Jason Noon[1], Ambily Abraham[1], Hanchen Li*[1], Florentina Rus[1], Deysy Pinto Rodriguez[1], David Gazzola[1], Alice Che Yu Lee[2], Dwight Bowman[2], Martin Nielsen[3], Anne Zajac[4], Joseph Urban[5], Katherine Petersson[6], Gary Ostroff[1], Raffi Aroian[1]. [1]University of Massachusetts Medical School, Worcester, MA, [2]Cornell University College of Veterinary Medicine, Ithaca, NY, [3]University of Kentucky, Lexington, KY, [4]Virginia Tech VA-MD College of Veterinary Medicine, Blacksburg, VA, [5]USDA Agricultural Research Service, Beltsville, MD, [6]University of Rhode Island College of the Environment and Life Sciences, Kingston, RI

Intestinal roundworms are amongst the important parasites of farm and companion animals in the United States. These roundworms are critical parasites of horses, cattle, sheep, pigs, dogs, etc. The parasites are capable of; 1) reducing reproduction of the animals; 2) decreasing their overall health, energy, and performance; 3) decreasing their productivity; 4) making animals more susceptible to disease; and 5) killing the animals. These parasites cause billions in lost economics. Although we have drugs to treat these infections, the parasites readily develop resistance to these drugs. For sheep, horses, and cattle there are already significant instances of the parasites being resistant to one or even several deworming drugs. Our laboratory has discovered a new, organic solution to this challenging situation, the Cry5B protein made naturally by the soil bacterium *Bacillus thuringiensis*, which is harmless to higher animals but toxic to parasitic worms, including *Haemonchus contortus*, *cyathostomes*, *Ascaris suum*, and *Ancylostoma caninum*.

Here we will present updated data on engineering *B. thurigiensis* to make our new therapy as cheap, easy, and approvable as possible. *B. thuringiensis* is a great bacterium for production of Cry5B because it is the native bacterium from which the protein comes: *B. thuringiensis* makes more Cry5B protein than any other bacterium we have put Cry5B into and makes it in a manner that is highly active against worms. However, *B. thuringiensis* is not a bacterium that is approved for live ingestion. To get around this issue, we have now genetically engineered *B. thuringiensis* so that it can be killed while keeping the protein highly active. This killed bacterium, called IBaCC, is active against key veterinary parasites. We are also modifuying the Cry5B protein to make it more active, e.g., against *Haemonchus contortus*, and will present data on efficacy in larger animals, such as dogs.

## 52

**Evaluation of internal parasite resistance in terminal-sire sheep breeds infected with *Haemonchus contortus***

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Breeds resistant to nematode parasites often have lower growth rates and decreased carcass quality compared to parasite-susceptible breeds. While mating terminal sires to parasite-resistant ewes has generated lambs with superior production traits, the level of resistance in progeny can vary greatly based on sire breed. The aim of this research was to evaluate parasite-resistance in Texel sheep during both a primary and challenge *Haemonchus contortus* infection when compared to known parasite-resistant and -susceptible breeds of sheep. Ten St. Croix, 10 Suffolk and 20 Texel lambs were randomly assigned to naïve (n=5 / breed) or infected groups (n=5 for St. Croix and Suffolk n=15 for Texel). Priming infection of 10,000 *H. contortus* L3 larvae were administered and infection persisted for 12 weeks before lambs were dewormed. Following 3 weeks of rest, primed lambs were challenged with 10,000 *H. contortus* L3 and infection was monitored for 7 weeks. Infection status was determined via fecal egg counts (FEC) and packed cell volume (PCV) weekly. No differences were found in either FEC or PCV between breeds during primary infection. During challenge infection St. Croix FEC were lower than both Texel and Suffolk lambs (535 vs 1917 and 3492 (eggs/g) respectively, $P < 0.001$). Hematocrit during challenge infection showed a similar trend. These data indicate that Texel sheep are more resistant to infection than Suffolk sheep and may serve as superior terminal sires for generating crossbred parasite-resistant progeny while maintaining economically important traits.

## 53

**Capture mechanisms of *Duddingtonia flagrans* on equine cyathostomin larvae**

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Cyathostomins also known as small strongyles are a group of parasitic nematodes infecting equids. Due to a life cycle that makes treatment difficult and acquired anthelmintic drug resistance over time they have become the most widespread pathogenic parasite of the horse. *Duddingtonia flagrans* is a nematode-trapping fungus showing promising preliminary results as a biological control agent for treatment of parasitic nematodes in livestock. Its spores have been shown to survive digestive tracts, then grow in fecal pats reduce the spread of the larval nematode stages onto pasture. The majority of existing literature is focused on fungal ability to combat sheep parasites; however, two *in vivo* horse studies demonstrated a reduction in viable L3 cyathostomin larvae and a reduction of larvae present on soil/foliage samples surrounding fecal pats after administration of fungal spores to feed. Species of nematode has shown a strong correlation with trapping time; previously described species *Panagrellus redivivus* and *Trichostrongylus sp.* were shown to be trapped and killed at only 4 and 15 hours of

interaction respectively, but species specific interactions between *D. flagrans* and cyathostomins have not been described.

The purpose of this study is to identify the effect of light on capture mechanisms of *Duddingtonia flagrans*, and to determine whether the fungus has a taxa-based preference for trapping specific cyathostomin larvae. We used time-to-capture as a measure of trapping efficacy. Initial results show equine nematodes being trapped at 24-36 hours of interaction under normal light conditions. Greatly reduced trapping efficacy in reduced light conditions was observed with larvae surviving and moving freely at 96 hours of interaction. The findings are unclear. Identifying factors related to nematode behavior patterns will give clues to the fungi's methods of nematode detection and inform efforts to use *D. flagrans* as an effective biological control for cyathostomins in horses.

## Session 10: Diagnosis - 2: Nematodes

### 54

**Comparison of Kato-Katz, mini-FLOTAC, and multi-parallel real-time polymerase chain reaction techniques for detection of soil-transmitted helminths in Feira de Santana, Brazil**

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Soil-transmitted helminth (STH) infections, primarily caused by the roundworm *Ascaris lumbricoides*, the hookworm species *Necator americanus* and *Ancylostoma duodenale*, and the whipworm *Trichuris trichiura,* affect over 1 billion people, with billions more at risk, especially in warm, moist climates. Current STH control efforts in Brazil are conducted using passive surveillance and incidental case finding, such as by the Schistosomiasis Control Program, which is limited to schistosomiasis endemic areas, leaving STH infection prevalence under-notified. Diagnostic testing for the STH relies mainly on the World Health Organization (WHO) recommended Kato-Katz thick smear method, a quantitative technique that has been shown to lack sensitivity. Other economical, feasible, and higher-accuracy diagnostic methods are needed to detect and combat STH, especially in areas of low endemicity. In the city of Feira de Santana, Brazil, we collected human stool samples and analyzed them using the WHO recommended Kato-Katz thick smear method, as well as with two more recently developed diagnostic methods, the mini-FLOTAC method and a multi-parallel quantitative polymerase chain reaction (qPCR) method. The mini-FLOTAC method allows for quick analysis of fresh or preserved feces with minimal equipment needed. The qPCR method allows for detection and quantification of parasites with a high degree of specificity and sensitivity, and is optimized to allow for inexpensive analysis of each sample. All three diagnostic methods are being analyzed and compared for both parasite detection and quantification. Both the mini-FLOTAC and qPCR methods offer feasible, higher-accuracy diagnostic alternatives to the standard Kato-Katz method, and will be useful in enabling a shift away from the current STH morbidity control approach and towards an elimination approach.

## 55

**The Propensity of Density: Determining Specific Gravity of Equine Parasite Eggs**

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The density of equine endoparasite eggs is sparsely investigated. Being that this density is utilized by common flotation techniques in qualitatively and quantitatively detecting intestinal parasite burden, this represents an area of potentially incorrect assumptions. The currently accepted standard for parasite egg flotation typically calls for a flotation solution density of e 1.20, but this may be unnecessarily high, potentially causing an increase in non-egg debris observed among samples. In quantifying their density, more specific techniques may be developed to target specific types of endoparasite eggs. It was expected that eggs of intestinal parasites would be significantly less than 1.25, as shown in past studies involving eggs of similar families of endoparasite found in other mammals. Saturated sugar salt solutions, ranging from 1.06 to 1.16, colored with dilute amount of food grade dyes (10,000:1) were placed one atop the other from most dense to least in fourteen 15 milliliter conical tubes. Concentrated suspensions of endoparasite eggs in water were placed atop this gradient and centrifuged at 800g for 20 minutes, allowing for eggs to move to a point of equilibrium. The entire column of liquid was removed in 0.5 ml increments and placed into McMaster egg counting chambers. The presence, type, and number of eggs at each level was optically observed by use of light microscopy and recorded. The mean density of strongylid eggs (n=1,516) was 1.045 (±0.03, $P<0.001$), mean Parascaris spp. egg (n=1651) density was 1.088 (±0.02, $P<0.001$), and the mean density of Anoplocephala perfoliata eggs (n=2,775) was 1.061 (±0.02, $P<0.001$). These findings have implications for potential new research directions such as separating eggs from mixed samples by type and identifying optimal specific gravities for flotation media used for fecal egg counting.

## 56

**Deep amplicon nemabiome sequencing reveals high species diversity and emerging benzimidazole resistance in gastro-intestinal nematode parasites of Canadian bison**

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The North American bison industry currently comprises almost 500,000 farmed North American Plains bison and there is a growing demand for for bison meat products. Bison appear to be more susceptible to parasitic nematode infections than cattle and parasite- associated clinical disease and production loss are commonly reported. In spite of this, there is very little published information on the prevalence, infection intensities or biology of gastro-intestinal parasites of bison. We have used deep-amplicon nemabiome sequencing to investigate the parasite species diversity on 58 commercial bison herds and three national park herds in Canada. The predominant species observed overall were *Cooperia oncophora* (43.12%) and *Ostertagia ostertagi* (39.86%) but there was a high level of species diversity in many herds with *Haemonchus placei, Trichostrongylus axei* and *Orloffia* bisonis also being common and predominating in some herds. An additional *Trichostrongylus* species was also observed in several farmed and natural bison herds that could not be identified to the species level based on currently available ITS-2 rDNA sequence databases.

We also used a newly developed deep-amplicon sequencing assay to investigate the presence of benzimidazole-associated mutations in the isotype-1 b-tubulin gene for multiple parasite species in the

58 bison herds. The F200Y ž -tubulin mutation was detected in *Ostertagia ostertagi* in several herds ranging in frequency from 0.5-15%. Discovery of benzimidazole resistant *O. ostertagi* within bison herds is a concern for both the bison and cattle industries as co-grazing and pasture rotation could lead to the spread of resistance. It also provides evidence that in-feed benzimidazole treatment on pasture, which is more widespread and longer standing in bison than in cattle, is likely to lead to the emergence of benzimiadazole resistance in *O. ostertagi*.

## 57

**Antibody concentrations against gastrointestinal nematodes in adult beef cows from the prairie provinces of western Canada**

Felicity Wills*, John Campbell, Cheryl Waldner, Fabienne Uehlinger. University of Saskatchewan, Saskatoon, SK

The objective of this research was to ascertain the seroprevalence and quantity of serum anti-*Ostertagia* antibodies of adult beef cows from the western Canadian prairie provinces, using the SVANOVIR® *Ostertagia ostertagi*-antibody enzyme-linked immunosorbent assay (ELISA).Serum from 2,064 adult beef cows from 106 herds from Alberta, Saskatchewan, and Manitoba, were collected in the fall of 2014. Frozen (-80°C) serum samples were analyzed in duplicate for the presence of anti-*Ostertagia* antibodies using the SVANOVIR® *Ostertagia ostertagi*-Ab ELISA kit. Optical density values were standardized as a ratio (ODR) using duplicate negative and positive control sera on each plate. Mean ODR were calculated for each cow. A cut-off point of 0.5 ODR was used to identify cows with high amounts of anti-*Ostertagia* antibodies.The mean cow ODR was 0.7 (Standard Deviation 0.3). Seventy-four percent (95% Confidence Interval 72-76) of cows had an ODR above the 0.5 ODR cut-offsuggesting a high amount of antibody.This is the first study demonstrating the use of serology for determining anti-*Ostertagia* antibodies in adult beef cattle. Mean ODR in this study were similar to those seen in mature dairy cattle, but higher than mean ODR from young beef stock when compared to published literature. In this study, 74% of ODR were above 0.5, a value that correlated with reduced milk production in dairy cattle. The relationship between adult beef cow ODR and production indicators should be explored further to assessthediagnostic potential of this test.

## 58

**Evaluation of a smartphone based automated parasite egg counting system to the McMaster and Wisconsin methods**

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With anthelmintic resistance on the rise among equine helminth parasites, it is increasingly more important to monitor anthelmintic efficacy through fecal egg counts (FEC). Unfortunately, however, this critical diagnostic tool is prone to several challenges including operator dependency, equipment requirements, method variability, and the time commitment. Therefore our lab has spent the last three years developing a smartphone based automated egg counting system. The most recent stage of development allows for automatic sample processing and utilizes the image capture of a smartphone while employing image analysis to identify and count equine strongyle eggs. The purpose of this study was to perform a full validation of the prototype system in comparison to the modified McMaster and Wisconsin techniques. FEC on naturally infected samples (n=165) were used to compare egg counts across techniques, while technique accuracy was evaluated by performing FECs on egg-count negative

samples spiked with a known number of strongyle eggs at levels of 7, 15, 35, 65, 125, 250, 500, and 1,000 eggs per gram. The McMaster and smartphone generated significantly higher counts than the Wisconsin ($p<0.0001$), and the there was no significant difference between counts generated by the McMaster and smartphone ($p=0.2428$). The smartphone was significantly more accurate than the Wisconsin ($p<0.0001$) and McMaster ($p<0.0001$) and there was no significant difference in accuracy between the McMaster and Wisconsin ($p=0.8452$). The smartphone system offers a standardized technique with reduced operator dependency and generates more accurate counts than both the McMaster and Wisconsin.

## 59

**Utilization of composite fecal samples for detection of anthelmintic resistance in gastrointestinal nematodes of cattle**

Melissa George*, Kelsey Paras, Sue Howell, Ray Kaplan. The University of Georgia, Athens, GA

Anthelmintic resistance in gastrointestinal nematodes of cattle is becoming increasingly prevalent worldwide. Presently, the fecal egg count reduction test (FECRT) is the only means available for detection of resistance to anthelmintics in cattle herds at the farm level. However, the FECRT is labor and cost intensive, and consequently is rarely performed on cattle farms unless for research purposes. If costs could be reduced, cattle producers might be more likely to pursue drug resistance testing on their farms. One approach to reducing the cost of the FECRT is the use of composite fecal samples for performing fecal egg counts (FEC), rather than conducting FEC on fecal samples from 15 to 20 individual animals. In this study FECRT were performed on 14 groups of cattle using both individual and composite FEC methods. There was little difference between the approaches with 98% agreement in mean FEC found between methods. Mean FEC based on individual counts ranged between 0 and 670.6 eggs per gram of feces, indicating that the results of this study are applicable to a wide range of FEC levels. There was greater than 95% agreement in drug efficacy between individual and composite sampling methods, demonstrating composite sampling is appropriate to evaluate drug efficacy. The use of composite samples was shown to reduce the number of FEC required by 79%. These data demonstrate that pooling fecal samples from a group of cattle and then performing repeated FEC on that composite sample yields results similar to performing individual FEC on those same animals, while substantially reducing the cost of performing a FECRT as compared to individual fecal samples. Furthermore, we have developed suggested methods for using composite samples in a FECRT, completed a cost comparison for this methodology, and described potential issues associated with the use of composite samples that must be considered.

# Session 11: Parasite Control - 3: Vaccines and Widespread Studies

## 60

**Safety of a *Haemochus contortus* vaccine (Barbervax) in camelids**

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Haemonchosis in camelids remains a challenging disease to treat and prevention has become increasingly problematic for veterinarians in the US. Barbervax has demonstrated safety and efficacy in

sheep and goats in Australia, but has not been evaluated in camelids. The vaccine utilizes a mixture of the parasite gut membrane enzymes including H-gal-GP and H11P, which are involved in the worm's ability to digest a blood meal from the host. In the study, we monitored the safety profile of the Barbervax vaccine in a group of adolescent alpacas. In this study, 12 alpacas (4-5 months of age) were randomized to vaccination with Barbervax or no treatment.Three doses of Barbervax were administered at 3 week intervals andinvestigators involved in animal monitoring and sample collection were blinded to the groupings. Clinical pathologic parameters were evaluated 7 days before vaccination, and 1 and 2 months post-vaccination. Daily clinical observations were made and specific observations regarding the injection site and rectal temperatures were monitored in each alpaca twice daily for 1 week following vaccination. Fecal egg counts, packed cell volume, and total protein were monitored following challenge with *H. contortus* larvae.Results showed that vaccinated alpacas maintained normal clinical pathologic parameters throughout the study period compared with non-vaccinated control alpacas. A moderate increase in rectal temperature for a median duration of 2 days was observed post-vaccination. Vaccinated alpacas were lethargic for 2-3 days following vaccination, maintained an appetite and no adverse injection site reactions were recorded. Animals showed no signs of anemia. In conclusion, the Barbervax vaccine is safe for use in healthy, young alpacas. An increased rectal temperature and decreased activity level may be expected for a short period of time following vaccination. Animals are currently being monitored for fecal egg counts during the post-vaccination grazing season. Support provided by the Alpaca Research Foundation.

## 61

**Dose optimisation of a candidate vaccine against *Cryptosporidium parvum* infection**

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An efficient vaccine against *Cryptosporidium parvum* infection would improve calf health and reduce cryptosporidiosis-related economic losses. Immunity can be transferred to pups from interferon gamma receptor knock-out (IFN$^{3}$ R-KO) mother mice immunized with four *C. parvum* surface proteins: CP2, p23, gp45 and gp900. Among these proteins, we reported that recombinant gp45 (r-gp45) is the most promising vaccine candidate in an active immunization protocol using IFN$^{3}$ R-KO mice. Threedoses of 40 µg r-gp45 induced a 72% parasite burden reduction in male IFN$^{3}$ R-KO mice. In an attempt to increase efficacy, 3 doses of 80 µg r-gp45 were tested in IFN$^{3}$ R-KO mice. This higher dose abrogated vaccine-induced partial protection. Therefore, a scale-down dose optimisation study was performed. Two doses of 20 µg r-gp45 showed partial protection (75% parasite burden reduction) similar to that induced by two doses of 40 µg r-gp45 (79% parasite burden reduction). Parasite burdens were confirmed by flow cytometry and histopathological analysis and immunological responses at different antigen doses were determined by cytokine and antibody level measurement. These data support that doses of 20 or 40 µg r-gp45 induced a better protective effect than 80 µg r-gp45. Co-administration of r-gp45 with CpG-B ODN-2006, a $T_H1$-inducing adjuvant, also abrogated vaccine efficacy. These findings support the protective role of $T_H2$ immune responses against *C. parvum* infection. Therefore, a new combination with aluminium hydroxide (alum), a $T_H2$-inducing adjuvant, is being tested and preliminary results will be presented. Female IFN$^{3}$ R-KO mice were resistant to the protective effect of all tested combinations of the r-gp45 vaccine; further studies will be needed to determine if it is a mouse strain-effect. An efficient vaccine against *C. parvum* infection is of fundamental interest to develop control measures against bovine cryptosporidiosis.

## 62

**_Eimeria_ oocyst cycling patterns in commercial broilers reared in conventional or antibiotic free production.**

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Coccidiosis is a common and costly intestinal disease affecting the global poultry industry caused by a number of protozoan parasites in the genus *Eimeria*. This disease has been historically controlled using in-feed anticoccidial medications. These medications are losing their effectiveness due to the selection for anticoccidial resistance. Vaccination using live coccidiosis vaccines is an increasingly common control strategy that is used in Canada in 'Raised Without Antibiotics' (RWA) programs. Oocysts per gram (OPG) is an easy, non-invasive, lost-cost technique to determine the level of coccidiosis infection and can be used to measure the success of coccidiosis control.

Fortycommercial broiler farms in southern Ontario were sampled during the summer of 2016, winter of 2017, or both, for a total of 60 flocks. 32 flocks were reared under conventional medication programs using antibiotics and anticoccidial medications.Twenty-eight flocks were reared under RWA production using the coccidiosis vaccine. Flocks were sampled on weekly basis following chick placement until five weeks of age. Samples consisted of fresh fecal droppings representative to one floor, from one barn per farm. Feces were processed for OPG. Flock performance results were collected. Vaccinated flocks had consistent OPG results across farms within seasons. Vaccinated flocks would peak in OPG on day 14 or day 21. Vaccinated flocks tended to peak on day 14 in the summer, and day 21 in the winter seasons. Flocks that peaked on day 14 appeared to peak higher than those that peaked on day 21. Vaccinated flocks peaked between 12,000 OPG and 260,000 OPG. There was a variety of anticoccidial programs that were used in medicated flocks. These medicated flocks were more variable in OPG counts compared to the vaccinated group. Some medicated flocks had negligible oocysts throughout. Six flocks had peak OPGs above 500,000, suggesting anticoccidial resistance.

## 63

**Decreased dissolved oxygen as a possible mechanism of increased persistence of _Trichomonas gallinae_ in the presence of organic material in water**

Kathryn Purple*, Richard Gerhold. University of Tennessee, Knoxville, TN

The transmission of *Trichomonas gallinae*, the avian protozoan parasite, from infected to naïve hosts may be facilitated by backyard birdbaths of varying cleanliness. *T. gallinae* persists longer, up to 20 hours, in distilled water with organic material added, mimicking soiled birdbaths. Of the many factors that organic material can alter in water, including pH, nutrient availability, and presence of environmental microbes, we hypothesized that the decrease in dissolved oxygen created by aerobic decomposition could be a key factor leading to increased persistence of this microaerophilic trichomonad. Through a series of experiments using plastic containers to simulate birdbaths we determined 1) the levels of dissolved oxygen in distilled water created by various amounts of organic material, 2) the amount of the enzyme Oxyrase needed to re-create those oxygen levels, and finally, 3) the persistence of two *T. gallinae* isolates in distilled water with artificially lowered dissolved oxygen. Oxyrase was added to 500ml distilled water in three treatment concentrations: 0%, 0.5% and 1%, which created dissolved oxygen levels of approximately 8-9ppm, 1-2ppm and 0-1ppm, respectively. The latter concentrations of dissolved oxygen were representative of those created with organic material. We evaluated one isolate from a Cooper's hawk (*Accipiter cooperii*) and one from a broad-winged hawk

(*Buteo platypterus*) by adding ~1x10$^6$ trichomonads to 500ml distilled water in our birdbaths in triplicate. Aliquots of 0.5ml taken at various time points from the birdbaths were inoculated into Hollander Fluid media, incubated at 37°C, and read by light microscopy every other day for 5 days. Both isolates persisted up to 18 and 30hrs in the 0.5% and 1% Oxyrase treatments respectively. In contrast, in unaltered distilled water, neither the COHA nor the BWHA isolate persisted past 4hrs. These results offer a possible method to deter trichomonads' persistence by keeping birdbaths clean and free of debris.

## 64

**A statistical approach for evaluating the effectiveness of heartworm drugs: what does 100% efficacy really mean?**

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Initial studies of heartworm preventive drugs all yielded an observed efficacy of 100% with a single dose. Based on this, the FDA required all products to meet this standard for approval. However, the majority of initial studies were performed using a single heartworm strain (TRS strain). Though a few studies may have used other strains, publications at that time almost uniformly failed to provide any details of the strain used. Consequently, this limited diversity of strains could not be representative of the full assortment of circulating *Dirofilaria immitis* biotypes. This issue deserves new attention, since it has become common for studies to yield <100% efficacy. Once observed efficacy falls below 100%, statistical problems arise because heartworm efficacy studies lack the statistical power to conclude that finding zero worms is different from finding a few worms. To address this issue, we developed a novel statistical model, based on a hierarchical modeling and parametric bootstrap approach that provides new insights to assess sources of variability encountered in heartworm drug efficacy studies. Using these newly established metrics we analyzed actual experimental data and performed data simulations to gain further insights into the optimal interpretation of heartworm efficacy data. We demonstrate conclusively that ZoeMo-2012 and JYD-34, which both were established from the same source dog, have significantly different levels of susceptibility to moxidectin. Additionally, we demonstrate conclusively that differences in efficacy reported in two published studies using the MP3 strain were not due to randomness, and thus must be biological. Our results demonstrate how statistical modeling can improve the interpretation of data from heartworm efficacy studies. Furthermore, our results provide strong evidence that heartworm 'strains' can change their susceptibility phenotype over short periods of time, providing further evidence that a wide diversity of susceptibility phenotypes exist among naturally circulating biotypes of *D. immitis*.

## 65

**In vitro efficacy of sarolaner against adult mosquitoes (*Aedes aegypti*)**

Tom McTier*, Erich Zinser, Nicole Kernell, Debra Woods. Zoetis, Kalamazoo, MI

The isoxazolines (sarolaner, fluralaner and afoxalaner) are rapidly becoming the preferred actives in companion animal ectoparasiticide products for controlling fleas and ticks on pets. Sarolaner has demonstrated activity against fleas, multiple species of ticks (*Ixodes, Rhipicephalus, Dermacentor, Amblyomma* and *Haemaphysalis* sp) and various species of mites (*Sarcoptes scabiei, Otodectes cynotis,* and *Demodex canis*) and in the prevention of the transmission of some tick-borne diseases (i.e. Lyme disease, anaplasmosis, babeseosis). As a broad-spectrum ectoparasiticide, with activity as a potent GABA antagonist of insect and acarine chlorine channels, it is possible that sarolaner could have activity

against other insect pests. Relatively little data are available on the effects of isoxazolines against mosquitoes. Thus, the purpose of this study was to determine the *in vitro* activity of sarolaner against mosquitoes. An assay was developed in which adult female *Aedes aegypti* mosquitoes were offered access to a blood meal for 1 hour that had been spiked with DMSO (negative control) or various levels of sarolaner. Dead females were counted at 24 hours post-feeding, and surviving females were crushed to determine if a blood meal had been consumed. Blood levels from 100 to 1 ng/ml were assessed in multiple replicates. Drug levels in blood e 50 ng/mL killed >95% of the female mosquitoes that consumed the blood meal within 24 hours of feeding. In three separate laboratory studies, plasma levels in dogs treated with a 2 mg/kg dose of sarolaner were >50 ng/ml from Day 0 through Day 35. These preliminary *in vitro* data suggest that mosquitoes that feed on dogs treated with Simparica® (minimum of 2 mg/kg sarolaner) will die within 24 hours of taking a single blood meal and that sarolaner levels will be sufficiently high in Simparica-treated dogs to kill mosquitoes for 35 days.

## Session 12: Epidemiology - 2: Nematodes

### 66

**Intestinal Nematode Prevalence in Dallas/Fort Worth Public Dog Parks: Free Fun but not Free of Worms**

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Public dog parks have gained popularity over the years and can be found in most urban areas in the United States. Although many dogs enjoy the social and physical benefits in public dog parks, there are potential medical risks including exposure to intestinal parasite infections.

To better understand parasite exposure risks in public dog parks, a pilot field study (100 dogs/10 dog parks) was conducted in the Dallas/Fort Worth area to assess the prevalence of common canine intestinal nematodes: *Ancylostoma caninum*, *Toxocara canis* and *Trichuris vulpis*. Additionally, three fecal diagnostic techniques [$NaNO_3$ passive flotation, sugar centrifugal flotation (Texas A&M Veterinary Diagnostic Lab) and ELISA antigen test (Dallas IDEXX Laboratories)] were compared. Lastly, a brief questionnaire was completed by dog owners/handlers to investigate the relationships between use of heartworm preventatives/intestinal parasite medication (HWIP) and prevalence of canine intestinal nematodes.

Parasite prevalence results were: Hookworms = 10%, Whipworms = 4% and Roundworms = 1%. Eight of the ten public dog parks had at least one positive test. Of the 14 dogs diagnosed with intestinal parasites, 50% were identified with passive flotation, compared to 64% with centrifugation and 86% with the IDEXX ELISA antigen test. Dogs whose owners/handlers reported year round use of HWIP were found to have fewer intestinal nematodeinfections (9%) than dogs whose owners/handlers reported them to either not be on HWIP (31%) or on HWIP, but not year round (20%).

These findings support: [1] the potential exposure risk to intestinal nematodes in public dog parks; [2] the choice of a particular fecal diagnostic technique used in practice can impact accuracy of intestinal nematode fecal results; and [3] the importance of monthly year round broad spectrum HWIP administration (including whipworm coverage).

## 67

**The prevalence and epidemiologic characteristics of canine *Baylisascaris procyonis* infections in the United States, 2013-2016.**

Sarah Sapp*, Michael Yabsley. University of Georgia, Athens, GA

Domestic dogs are hosts to many well-recognized zoonotic helminths of public health importance. However, little is known about *Baylisascaris procyonis*, the raccoon roundworm, in dogs. In addition to developing larva migrans as intermediate hosts, dogs can serve as alternative definitive hosts with patent intestinal *B. procyonis* infections. Despite the potentially serious public health implications, broad-scale prevalence and distribution of cases are unknown. To characterize the current status of *Baylisascaris* in dogs in the United States, we acquired nationwide fecal floatation results from a commercial veterinary diagnostic laboratory. *Baylisascaris* spp. eggs were detected in 504/9,486,672 (0.005%) fecal samples from 2013 to 2016. Prevalence was significantly lower in the Southern, Central, and Western regions ($p<0.0001$) compared with the Northeastern referent category, which somewhat reflects the known prevalence of *B. procyonis* in raccoons. However, positive dogs were detected in nine states where *B. procyonis* has not been reported which could be unrecognized endemic areas or travel-related infections. Positive dogs ranged from 1 month to 15 years old, and most positives were from large breeds (69%). Among positive dogs with a breed indicated, most were sporting (41%) and working group (20%) breeds. These data reveal some interesting aspects of canine baylisascariasis, including evidence for vertical transmission of *B. procyonis* in young puppies and the occurrence of non-canine ova indicating some dogs with *B. procyonis* eggs in feces could have acquired via coprophagy. Regardless of the source of eggs, this data demonstrate that dogs can shed *Baylisascaris* into domestic environments and may present a health hazard. Overall, prevalence among these dogs is low, but this may be biased because sampled dogs were likely owned dogs receiving quality veterinary care. Routine parasitic testing, preventive use, and restrictions on coprophagy should be encouraged to reduce risk of human or animal exposure to infectious eggs.

## 68

**Equine strongyle egg shedding patterns in the western region of the state of São Paulo, Brazil**

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Equines are hosts to a variety of gastrointestinal parasites which represent significant threats to their health. The western state of São Paulo, Brazil, has an estimated population at 13,000 horses which represent an important economic resource for the region. Despite this, there are no studies regarding parasitic infection in this region. For this reason, this study was carried out in 9 cities and 27 properties around Presidente Prudente (São Paulo, Brazil), from August 2016 through March 2017 to evaluate the prevalence of strongyles and to identify associated factors. A total of 171 animals aged 2 years or older were enrolled in the study. Fecal samples were collected and a questionnaire regarding the characteristics of the property, management of the animals, and owner perception of equine parasites was recorded. Fecal egg counts (FECs) were determined in triplicate. All farms and 91.8% (157) of the horses returned positive FEC. Multivariate mixed linear model analysis revealed significant differences between farm types ($p=0.0012$). Ranches were significantly lower in fecal egg counts when compared to riding clubs and boarding stables, respectively. Working horses ($p=0.0198$) and horses used for recreation ($p= 0.015$) both had higher FEC than sport horses. FEC of Horses dewormed two to three months prior to the study were lower than horses treated four to five ($p=0.0126$) and more than five

months (p=0.0105) prior. Horses that stay most of the day in stalls had significantly lower FEC (p=0.0111) than those kept on pasture. The results obtained in this study revealed several factors significantly associated with FEC. Thus, this information can be used by veterinarians and horse owners to improve control for intestinal parasites among equids in this region.

## 69

**Observation of *Strongyloides westeri* burden in naturally infected foals at 4-8 months of age**

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*Strongyloides westeri* is a threadworm parasite found mainly in foals starting as an adult at approximately 2 weeks old up to about 4 months. This parasite is associated with small intestinal enteritis and diarrhea as well as skin irritation and a clinical syndrome called "frenzied behavior" due to percutaneous invasion. The aim ofthis study was to investigate *S. westeri* parasite burdens in age groups older than the initial lactogenic transmission phase. Secondary aims were to examine the impact of host age and gender on worm burden and egg output in naturally infected foals. Thirteen foals were enrolled in the study, exposed to natural infection with *S. westeri* and were humanely euthanized at ages ranging from 89 to 221 days old. Egg counts per gram of feces (EPGs) were determined using the Mini-FLOTAC method. The worms were retrieved from the mucosa of the anterior half of the small intestine using a digestion method, and counted under a dissecting microscope. The foals were all observed to be healthy with no signs of parasitic disease. Foals at 4-5 months of age had significantly higher *S. westeri*worm and egg counts compared to those aged 6-8 months (p<0.0001). Euthanasia month had a significant effect on worm counts (p=0.0470) as well as fecal egg counts (p=0.0045). Foals at 7 and 8 months of age harbored the parasite and while egg and worm counts declined markedly in the 6-8 month age range, they were not eliminated completely. This could either reflect a new infection acquired orally or transcutaneously, or a subset of adult intestinal parasites acquired via the lactogenic route and surviving for longer time periods. This study provided new information about *S. westeri* infections in foals older than the normal lactogenic transmission phase.

## 70

***Angiostrongylus cantonensis* in wild rats (*Rattus rattus*), and native and non-native terrestrial snails in Florida.**

Heather Walden*[1], John Slapcinsky[2], Shannon Roff[1], Jorge Mendieta Calle[1], Zakia Diaz Goodwin[1], Jere Stern[1], Rachel Corlett[1], Julia Conway[1], Antoinette McIntosh[1]. [1]University of Florida, Gainesville, FL, [2]University of Florida Museum of Natural History, Gainesville, FL

The parasitic nematode *Angiostrongylus cantonensis* is a major cause of eosinophilic meningitis in humans, and documented in other incidental hosts such as birds, horses, dogs and non-human primates. It is endemic in Hawaii, and there have been sporadic reports in the southern continental United States. This parasite uses rats as definitive hosts and snails as intermediate hosts. In this study, we collected potential definitive and intermediate hosts throughout Florida to ascertain the geographic distribution in the state: Rats, environmental rat fecal samples, and snails were collected from 18 counties. Classical diagnostics and morphological identification, along with molecular techniques were used to identify nematode species and confirm the presence of *A. cantonensis*. Of the 171 *Rattus rattus* collected, 39 (22.8%) were positive for *A. cantonensis,* and 6 of the 37 (16.2%) environmental rat fecal samples collected in three of the surveyed counties were also positive for this parasite by real time PCR. We examined 1,437 gastropods, which represented 32 species; 27 (1.9%) were positive for *A. cantonensis* from multiple sites across Florida. Three non-native gastropod species, *Bradybaena similaris, Zachrysia*

*provisoria,* and *Paropeas achatinaceum,* and three native gastropod species, *Succinea floridana, Ventridens demissus,* and *Zonitoides arboreus,* which are newly recorded intermediate hosts for the parasite, were positive for *A. cantonensis.* This study indicates that *A. cantonensis* is established in Florida through the finding of adult and larval stages in definitive and intermediate hosts, respectively, throughout the state. The ability for this historically subtropical nematode to thrive in a more temperate climate is alarming, however as the climate changes and average temperatures rise, subtropical gastropod distributions will probably expand, facilitating the spread of *A. cantonensis* in more temperate areas. Accidental infections may be avoided with greater awareness of host species and prevalence of *A. cantonensis* in the United States.

## 71

**Gastrointestinal nematode prevalence and species composition in breeding-age heifers on Canadian dairy farms**

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Gastrointestinal nematodes (GIN) are a threat to the health and welfare of cattle worldwide and have substantial detrimental effects on cattle productivity. Furthermore, evidence of anthelmintic drug resistance is increasing worldwide. There is a scarcity of information regarding the GIN burden in Canadian dairy heifers. Additionally, there is no information on the predominant nematode species present in these heifers on which to make evidence-based recommendations for sustainable control. Therefore, fecal samples (n=2,369) were collected from breeding-age heifers on 306 dairy farms from all 10 Canadian provinces. Eggs per gram of feces (EPG) were determined using the Modified Wisconsin Sugar Flotation Technique. Predominant GIN species at the farm-level were identified by deep amplicon nemabiome sequencing of the ITS-2 rDNA locus of nematode larvae. Population-averaged prevalence and overall EPG, accounting for clustering on farms, were 20.9% (95% CI: 17.2 – 24.6%) and 1.10 EPG (95% CI: 0.64 – 1.55 EPG), respectively. Individual heifer egg counts ranged from 0 – 141 EPG (median: 0 EPG; range: 0 – 70.6 EPG). The predominant species were *Cooperia oncophora* and *Ostertagia ostertagi*. Although the results of this study are consistent with the literature for young cattle in temperate climates, they provide much needed epidemiological data on GIN in Canadian dairy heifers. The use of the high-throughput deepsequencing assay to determine nematode species, in combination with traditional egg count methods, provides improved opportunity to apply evidence-based, sustainable control strategies and to better investigate treatment efficacy in the future.

# Session 13: Innovative Research

## 72

**Bovine *Babesia* spp. Recovered after Almost Three Decades in Cryostorage and Comparison of Different Donors of Bovine Erythrocytes and Serum**

Amer Alhaboubi*, Kimberly McCormack, Maria Esteve-Gassent, Patricia Holman. Texas A&M University, College Station, TX

Cultured *Babesia bovis* and *Babesia bigemina* were recovered from liquid nitrogen storage nearly 30 years after they were cryopreserved and reintroduced to microaerophilous stationary phase (MASP) culture. Two *B.bigemina* cryostocks (frozen in 1986 and 1987 at Texas A&M University, College

Station, Texas) were recovered and cultured in erythrocytes and serum from 4 different cattle. The comparison revealed that erythrocytes and serum from only one of the four animals supported growth of *B.bigemina.* Two *B.bovis* cryostocks (both frozen in 1986) were recovered from liquid nitrogen storage and cultured in erythrocytes and serum from the suitable donor. In the third passage after recovery, *B.bovis* cultures were cryopreserved. Six months later they were successfully recovered using #913 erythrocytes and serum. This study shows that *B.bovis* and *B.bigemina* stored nearly 30 years in liquid nitrogen can be successfully recovered in the MASP system. This study also confirms previous observations that selection of a suitable bovine donor of erythrocytes and serum is critical to the success of the culture.

## 73

**Cryogenic preservation of *Dirofilaria immitis* microfilariae, re-activation and subsequent development in the mosquito and vertebrate hosts**

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The cryopreservation of filarial nematodes has been studied for nearly 70 years. Largely, these studies examined the efficacy of cryopreservation methods by using the post-thaw survival of microfilariae (mf) and the development to the third-stage larval form (L3) following inoculation into a competent insect vector. Only one study reported complete re-establishment of a filarial nematode (*Brugia malayi*) lifecycle in a competent vertebrate host from cryopreserved stock. Expanding on this previous research, a cryopreservation method was applied to cryopreserve the mf of the dog heartworm, *Dirofilaria immitis*. A combination of cryoprotectants, dimethyl sulfoxide (DMSO) and polyvinyl pyrolidone (PVP) at 6% and 4 mM, respectively, provided acceptable post-thaw survival of mf that developed into infective L3 larvae in *Aedes aegypti*. Infective L3 larvae were developed from cryopreserved and freshly collected mf in mosquitoes, inoculated into ferrets and dogs, and successfully developed into adults in both hosts. Fewer adult heartworms derived from cryopreserved stocks of mf were recovered from ferrets, and were smaller by weight and length compared to adults from freshly collected mf. The onset of patency (circulating mf) occurred at similar post-inoculation times and at similar mf densities in dogs infected with L3s sourced from cryopreserved stocks or freshly collected mf. The results from these direct comparisons show cryopreserved mf can develop into adults in the ferret and dog and complete the heartworm lifecycle in dog. These data suggest that cryopreservation of mf could potentially be used to maintain specific isolates of *D. immitis* (and other filarial mf), without the need for canine hosts, minimizing the use of dogs and greatly reducing the cost to maintain these isolates. Future work needs to be done to determine the maximum longevity of mf in the cryopreserved state.

## 74

**Retrospective characterization of the *Brugia pahangi* lymphatic infection model in beagles**

Michael Dzimianski*, John McCall. University of Georgia, Athens, GA

The canine lymphatic filariasis model was used as a secondary screen for the evaluation of candidate drugs for potential efficacy against human filarial parasites. Fifteen studies using a total of 639 dogs were done. Each dog was infected with a total of 200 infective $L_3$ of *Brugia pahangi* by subcutaneous injection into the dorsum of either one hind paw (108 dogs) or equally divided into both hind paws (531 dogs). Patency occurred in 92.6% and 97.7% of the dogs infected in one and both hind paws, respectively. The incidence of peripheral lymphedema ranged from 0 to 30.6% for the 15 studies with an average incidence of 17.6% for dogs infected in only one hind paw and 13.6% for those infected in both

hind paws. In general, most dogs with lymphedema were either amicrofilaremic or had a low level microfilaremia (<20 microfilariae/20 µl). When a complete necropsy was done on 32 untreated dogs, most worms (84.6%) were recovered from lymphatics afferent to the popliteal lymph nodes of the infected limb. Adding the number of worms recovered from the lymphatics afferent to the superficial inguinal and medial iliac lymph nodes of the infected limbs increased the recovery to 90.4%. Sixteen untreated dogs infected in one hind paw and necropsied 6 months post-infection (PI) had an average recovery of 32.1 worms (std. dev., 19.8, range, 5-71).Worms recovered from untreated dogs infected in both hind paws and necropsied 6-7 months PI (22 dogs), 10-12 months PI (54 dogs), and 15-18 months PI (14 dogs) numbered 57.9 (std. dev., 28.2, range, 22-105), 30.7 (std. dev., 27.2, range, 0-94), and 10.8 (std. dev., 18.9, median, 1, range, 0-54), respectively. Approximately equal numbers of male and female worms were recovered. Most dogs with a persistently low microfilaremia or amicrofilaremic with lymphedema had no worms at necropsy.

## 75

**Pharyngeal pumping in fourth stage larvae of *Haemonchus contortus***

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Feeding in nematodes involves coordinated and rhythmic contractions in the muscles of the pharynx. This process of pharyngeal pumping is necessary for the parasite to feed itself and is both an attractive target for the development of new antiparasitic drugs and the probable target of some of the existing ones. We have used video-microscopy, fluorescent dye ingestion and electrophysiological recordings to study the physiological and pharmacological properties of pharyngeal pumping in *H. contortus,* in the hope of optimizing an experimental platform for medium-throughput screening of potential anthelmintic compounds that impair the worms' health or feeding. Our studies focused on the fourth larval stage (L4) of the parasite life cycle. Using video-microscopy at room temperature, we recorded pharyngeal pumping events in L4s taken from gerbils, and showed that pumping was stimulated by exogenous application of 5-hydroxytryptamine (5-HT, also known as serotonin), the neuromodulator that activates feeding in other nematode species. However, the rate of pumping was somewhat irregular and erratic. Pharyngeal pumping in L4s cultured from L3s in vitro was studied using two methods: fluorescent dye ingestion and electrophysiology. Dye ingestion was most reliable in serum-augmented culture medium containing a low concentration of 5-HT. Microfluidic devices (chips) developed to record electropharyngeograms (EPGs) from other parasitic and non-parasitic nematodes were customized for use with the *H. contortus* L4. Both 8-channel and 1-channel (ScreenChip) microfluidic chips were used, held at ~37 ºC. EPGs were recorded in L4, with the typical pump waveform seen in other nematodes. However, the activity was irregular compared to other species, including human hookworm L4, that have been recorded in microfluidic chips. It is not yet clear whether the feeding activity of *H. contortus* differs intrinsically from that of other species, or whether we have simply not identified optimal conditions (e.g., culture medium components) for inducing feeding behavior.

## 76

***Pseudocapillaria tomentosa* in zebrafish, a model for nematode intestinal microbiome studies**

Christopher Gaulke, Michael Kent*, Sharpton Thomas. Oregon State University, Corvallis, OR

*Pseudocapillaria tomentosa* is a common and pathogenic intestinal nematode in zebrafish in researcher facilities. Where it is a serious concern to researchers, the zebrafish/*P. tomentosa* model provides an opportunity as a high-throughput model to study host/nematode interactions.

Components of the microbiome may interact with parasites to influence their success in the gut, while parasite infections are also known to influence the composition of the gut microbiome. We evaluated the longitudinal changes in the gut microbiome structure during experimental *P. tomentosa* infection in adult zebrafish. The composition of the microbiome changed rapidly during the infection, and these changes were associated with parasite stage of development (larvae vs adult worms) and parasite abundance. Individual bacteria taxa covaried with parasite abundance in the intestine, intimating the gut microbiome may influence parasite burden. Associations between taxa and parasite abundance in some cases appeared to be phylogenetically patterned. Strong positive associations were observed between OTUs phylotyped to Proteobacteria and abundance of adult parasites and the presence of parasite eggs (an indicator of worm maturity). The worm larvates in about 5-7 d, and as with other capillarids and whipworms, the infection is initiated by ingestion of larvated eggs. We are investigating factors that induce hatching, and in our first experiments we found that exposure of larvated eggs to zebrafish fish intestines caused a significant increase in hatching compared to PBS controls, and feces isolated from intestines and gut bacteria also caused an increase in hatching, but less profound.

## Session 14: Epidemiology - 3: Ticks and Mix

### 77

**Ticks from pet cats in the United States: species, stages, and patterns of infestation**

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Ticks are an important but under recognized parasitic threat to cats in many areas of the United States. To characterize the species and stages of ticks most commonly recovered from cats, we conducted a survey of ticks removed from cats at veterinary practices in 18 states from 8 regions of the country from April 2016 – March 2017. A total of 737 ticks were submitted from 328 cats from 38 different veterinary practices. A single tick was submitted from the majority of cats, with a mean infestation intensity of 2.2 (range 1-46). The most common tick was *Ixodes scapularis*, accounting for over half of all submissions, followed by *Amblyomma americanum* (24%) and *Dermacentor variabilis* (18%); a few *I. pacificus*, *I. banksi*, *D. occidentalis*, *A. maculatum*, *Rhipicephalus sanguineus*, and *Otobius megnini* were also submitted. A majority of ticks were adults (77%); females predominated in all adult tick submissions. Immature ticks included both nymphs and larvae and were primarily *I. scapularis* and *A. americanum*. Ticks were collected in every month; the largest numbers of submissions were in May and October. Adults of *A. americanum* were most commonly submitted April through June, *D. variabilis* May through July, and *I. scapularis* October through February. Adult *I. scapularis* were most commonly recovered from the dorsal head and neck, *A. americanum* from the ventral thorax, abdomen, and perianal region, and *D. variabilis* from the head and neck, especially the ear pinna. Cats with ticks were predominantly male (59%) and altered (77%), and most reportedly spent > 30% of time outdoors, although 1 in 5 were reported to live primarily (d 30% of time) or entirely (100%) indoors. These results indicate that pet cats, including those that live primarily indoors, are at risk of tick infestation and would benefit from routine tick control.

## 78

**Morphological identification of ticks and detection of select tickborne pathogens in ticks collected in East Tennessee**

Nathan Crilly*, John Schaefer, Aaron Baumann, Aly Chapman, Rick Gerhold. University of Tennessee College of Veterinary Medicine, Knoxville, TN

Because of the reported prevalence of Rocky Mountain Spotted Fever (RMSF) in Tennessee and the possibility of *Borrelia burgdorferi,* the causative agent of Lyme borreliosis becoming established in the state, understanding the distribution of ticks and tickborne diseases (TBD) across Tennesseeis critical. However, to date there has been little comprehensive research on ticks and TBD in East Tennessee. In this study, our goal was to determine the year-round distribution of vector tick species in East Tennessee, as well as the prevalence of *Borrelia burgdorferi* and Spotted Fever Group Rickettsiae (SFGR). Over a period of a year, 258 ticks were collected from veterinary clinics and other sources. Each tick was identified to species and life stage, and all specimens of *Dermacentor variabilis* and *Ixodes* spp. were screened for rickettsial or *B. burgdorferi* DNA, respectively. Of the 258 ticks collected, the predominant species was *Amblyomma americanum* (74.7%), followed by *D. variabilis* (15.2%), *I. scapularis* (7.4%), *Rhipicephalus sanguineus* (1.9%), and *Ixodes brunneus* (0.8%). *I. scapularis* was more abundant than expected from previous research, especially in Hamilton County. *A. americanum* and *D. variabilis* were most abundant in spring, while *Ixodes* spp. were most abundant in winter. Of the 39 *D. variabilis* collected, 3 were positive for rickettsial DNA, which shared highest sequence identity with *Rickettsia montanensis*. Of the 22 *Ixodes* spp. collected, none were positive for *B. burgdorferi* DNA. Our major finding was an unexpectedly high population of *I. scapularis* in East Tennessee. As in other studies, we were not able to identify the causative agent of RMSF, *R. rickettsii*. However, we did identify DNA from the related SFGR *R. montanensis*. Recent evidence has shown that *R. montanensis* may cause disease in humans. Thus, it is possible that *R. montanensis* may be implicated in some cases of RMSF reported in Tennessee.

## 79

**Prevalence of internal parasitic infection in free-roaming cats in Oklahoma based on centrifugal fecal flotation**

Yoko Nagamori*, Rebecca Duncan-Decocq, Eileen Johnson. Oklahoma State University, Stillwater, OK

There are only a few surveys conducted on prevalence of internal parasitic infection in free-roaming domestic cats (*Felis catus*). Data on the prevalence of parasites in free-roaming cats can aid in justification for parasitic control in owned cats since they share a similar environment. To determine the prevalence of internal parasites, fecal samples were collected from 846 free-roaming cats that presented to a trap-neuter-return (TNR) clinic at Boren Veterinary Medical Hospital, Oklahoma State University between February 2015 and April 2016. Feces were collected from cage traps when available or collected rectally using a disposable fecal loop. One to five grams of fecal samples were examined by a centrifugal fecal flotation test with 33% zinc sulfate solution. The most common internal parasite observed in feces was *Toxocara cati* eggs (44.6%; 377/846), followed by *Alaria* spp. eggs (13.4%; 113/846), *Ancylostoma* spp. eggs (11.2%; 95/846), *Cystoisospora* spp. oocysts (9.7%; 82/846), *Taenia taeniaeformis* proglottids/eggs (7.7%; 65/846), *Dipylidium caninum* proglottids/egg packets (4.5%; 38/846), *Physaloptera* spp. eggs (2.2%; 19/846), *Eucoleus aerophilus* eggs (1.4%; 12/846), *Giardia* cysts (1.2%; 10/846), and small coccidian oocysts – approximately 10–12 µm in diameter (0.1%; 1/846). A few ectoparasite species, *Demodex gatoi* adults (0.5%; 4/846) and *Cheyletiella* spp. adults (0.1%; 1/846), were also observed on fecal flotation. Approximately 63.9% (541/846) of free-roaming cats were

infected by at least one parasite, and 24.9% (211/846) of cats were infected by multiple parasites. Our findings indicate that parasitic infections remain prevalent in free-roaming cats and emphasize the importance of broad spectrum internal parasitic control for owned cats.

## 80

**Detection of *Aeromonas salmonicida* in infected salmonid fish and their parasitic copepods**

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Whereas arthropod transmission of bacterial diseases is well recognized in terrestrial host species, there is little evidence of this phenomenon in the aquatic environment. Furunculosis, caused by the bacterium *Aeromonas salmonicida,* is a severe systemic disease of captive and wild salmonid fishes. Fish to fish transmission in captivity has been thoroughly investigated, but little is known about the potential vectors of this pathogen in wild fish populations. We are studying the parasitic copepod *Salmincola californiensis* as a vector for *A. salmonicida*. Reproduction of the copepod entails development of larvae within egg sacs that remain attached to the female. We hypothesize that female copepods may transmit the pathogen vertically, leaving detectable levels of the bacteria in egg sacs or in their larvae within. Six Chinook salmon smolts infested with *S. californiensis* were challenged with a green-fluorescent protein strain of *A. salmonicida* (GFP-449) by IM injection. Tissues and copepods were then harvested from the six exposed and six control fish. Presence of GFP-449 in fish tissues and copepod egg sacs was determined by polymerase chain reaction (PCR). Four of the six challenged fish had detectable GFP-449 in renal and splenic tissues. Some copepod egg sacs from fish exposed to the bacterium had detectable GFP-449 in one or both egg sacs. In contrast, two treated fish had no detectable GFP-449 in either their tissues or copepod egg sacs. Tissue samples and copepod egg sacs from control fish also did not have detectable GFP-449. The presence of GFP-449 in the egg sacs of copepods removed is the first step suggesting that *Salmincola californiensis* may serve as a vector for the transmission of *Aeromonas salmonicida* between wild salmonid fish.

## 81

**Potentially zoonotic and non-zoonotic parasites in domestic dogs in rural, urban and First Nations communities across Ontario, Canada: Preliminary results from 17 study sites.**

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A wide range of parasitic infections are prevalent in Canadian domestic dogs. However, no study to date has examined the prevalence of potentially zoonotic parasites in dogs in varied communities across Ontario. Access to permanent veterinary services is limited in some areas of Ontario and veterinary clinics are not usually found on First Nations reserves. Human exposure to zoonotic parasites may be elevated where free-roaming dogs have access to contaminated water and infected raw meat through scavenging. Wild or domestic dogs may serve as bridges for such zoonoses. There is also concern regarding transmission of parasitic infections from infected to healthy dogs within these communities. Our goal was to determine the prevalence of potentially zoonotic and non-zoonotic parasitic infections in domestic dogs that may impact the health of humans and domestic dogs in these Ontario communities. Fecal samples (n=151) from dogs in rural, urban or First Nations communities were collected to determine the prevalence of parasites identified in each community; parasites with potential zoonotic risk to humans were of particular interest. Samples were processed using the Cornell-Wisconsin centrifugal flotation method employing sucrose flotation medium (SGof 1.27-1.33). Preliminary results showed that the overall prevalence (at least one parasite identified) of intestinal parasites in the canine fecal samples was 18.5% (n=28); only 3 dogs were infected with more than one

parasite. Protistan parasites detected included *Giardia* sp. and *Cystoisospora* sp. and the helminths detected included hookworms (*Ancylostoma*/*Uncinaria* sp.), ascarids (*Toxocara*/*Toxascaris* sp.) and whipworms (*Trichuris* sp.). Of the 31 parasite infections identified, 19% (6/31) were potentially zoonotic and 81% (25/31) were considered non-zoonotic. This study serves as a preliminary assessment of the prevalence of dog parasites in select Ontario communities; potentially zoonotic parasitic infections were found that may warrant more active surveillance and, potentially, more active control.

## President's Symposium – Veterinary Parasitology: The Climate is Changing

## 82

**Prospects for manipulating the genome of *Strongyloides* spp.: transgenesis via the male and female germlines and the advent of CRISPR/Cas9 gene disruption and editing.**

James Lok, University of Pennsylvania, Philadelphia, PA

Descriptive genomics of parasitic nematodes has advanced rapidly in the last two decades, but lack of robust methods for transgenesis and gene disruption or silencing has hampered functional studies arising from these new resources. The existence of free-living adults in the life cycles of *Strongyloides* spp. and related genera makes these parasites apt subjects for transgenesis, and reliable methods for transient promoter-regulated transgene expression have been available for *Strongyloides* and *Parastrongyloides* since 2006. Standard methods for transgenesis in *Strongyloides* spp. involve microinjecting transgene constructs into the gonadal syncytia of free-living female worms. Plasmid constructs with appropriate regulatory sequences are actively expressed in promoter-regulated fashion in the F1 generation of progeny, but their expression is silenced in subsequent generations. By contrast, integrating plasmid-derived sequences into the *Strongyloides ratti* chromosome via the *piggyBac* transposon have enabled derivation of parasite lines that stably transmit and express transgenes indefinitely through sequential generations of host and culture passage. A new method of gene delivery involves microinjecting plasmid constructs into the distal testes of free-living male worms. Mating of parental free-living males and females transformed with distinct reporter transgenes gave F1 progeny inheriting both markers from the respective parents. Elements of the CRISPR/Cas9 system for gene mutation have been introduced into the germlines of free-living female *S. stercoralis* by microinjecting encoding plasmid vectors, and mutations in F1 progeny have been ascertained by PCR. Using the CRISPR/Cas9 system we have inserted a disrupting oligonucleotide into a precise target site in the *S. stercoralis* developmental regulatory gene *Ss-daf-16*. Thus, transgenesis in *Strongyloides* spp. provides the means to deploy CRISPR/Cas9 technology for gene disruption and editing in these parasites. Transgenesis via both male and female germlines provides a means to make a CRISPR-induced mutation in both maternal and paternal alleles of a target gene within a single generation.

## 83

**Prioritizing parasite intervention targets using multi-omics computational approaches**

Bruce Rosa*[1], Joseph Urban[2], Dolores Hill[2], Valsin Fournet[2], Yue Xie[2], Allyson Dailey[3], Robin Couch[3], Dante Zarlenga[2], Makedonka Mitreva[1]. [1]Washington University in St. Louis, St. Louis, MO, [2]USDA, Beltsville, MD, [3]George Mason University, Manassas, VA

With technological improvements and the decreasing cost of "omics" technologies, researchers now have a massive amount of high-throughput genomic, transcriptomic and proteomic data available to undertake knowledge-based identification of parasite intervention targets. Parasitic nematode vaccines

are in high demand due to the rise in drug resistance coupled with occupational exposure, as well as drug residues in feed and sub optimal pasture management. Here, I present our progress on a reverse vaccinology approach using bioinformatics to screen parasite genomes to identify putative immunoreactive antigens for experimental validation. Prioritizing targets using information spanning multiple species and dataset types is a challenging bioinformatic task. As an example of a complex multi-omics computational approach, we (i) identified putative vaccination targets conserved among gastrointestinal nematodes by constructing orthologous protein families (OPFs) using genomes spanning the phylum *Nematoda*, (ii) prioritized OPFs based on taxonomic conservation, expression profiles during the life cycle, proteomics data and secretion potential and (iii) experimentally tested the top three prioritized candidates. All three prioritized candidates tested positive in ELISA testing, and are undergoing further experimental validation. As an orthogonal approach we also intersected our prioritized candidates with experimentally identified differentially detected proteins (immunoblotting parasite-susceptible vs resistant pig antibodies) and identified additional candidates for testing, demonstrating its use for the analysis of novel experimental data as it is produced. The next step is to perform more high-throughput screening using protein microarrays, requiring additional prioritization. Previously, using a novel genome assembly, gene functional annotations and transcriptome datasets for the parasitic nematode *Necator americanus,* we generated a protein microarray of 623 target proteins, identifying 22 serum immunoreactive proteins (using sera from 200 individuals). This approach both identifies parasite vaccine targets, and validates a “proof-of-principle” demonstrating the use of vast omics databases to solve real problems in attenuating human and animal diseases.

# 2017 POSTERS

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# POSTERS

## 84

**Lack of prolonged benefit for a triple combined anthelmintic treatment and rotational grazing on an anthelmintic-resistant *Haemonchus contortus* population from a winter climate.**

Anwar Sarah, Pratiksha Khanal*, Priscilla Heliso, Larry Hoiler, Susan Holler, Michael Hildreth. South Dakota State University, Brookings, SD

Anthelmintic resistance is a growing problem for *Haemonchus contortus*, even among sheep and goat herds located in winter climates that are lethal to its free-living juvenile stage. Because survival in these climates is entirely dependent on the tissue-dwelling fourth-stage juvenile, researchers have speculated that it may be feasible to aggressively treat and prevent transmission of *H. contortus* enough to eradicate it from herds in these regions. This study evaluated these speculations using a flock of ewes from the Northern Plains with a *H. contortus* population (85% *Haemonchus*. 5% *Teledorsagia* and 10% *Trichostrongylus*) exhibiting benzimidazole and avermectin resistance. Prior to first release into paddocks in the spring of 2014, ewes were given a triple anthelmintic treatment consisting of moxidectin (Cydectin), followed by albendzole (Valbazen), and followed by levamisole (Prohibit®). Pre- and 2-week post-treatment fecal egg counts (FECs) for 250 ewes showed a 99.99% FEC reduction from 3650 eggs per gram (EPG) to 0.17 EPG. Ewes with less than 1 EPG were grazed 2-3 times through 7 paddocks (mean 5.90 hectares) from June 30 to November 4, 2014. Bi-monthly FECs (N=30) showed egg output remain very low until 10 weeks on paddocks (2 weeks after ewes first rotated onto a previously grazed paddock). Output peaked on the 16th week at 42.1 EPG. During the following year, mean spring FEC was only 66.1 EPG and only 5.1 for the fall; trichostrongyle population diversity was similar the previous spring. Unfortunately, by the spring of 2016 egg output had increased to 1116.0 and remained high in 2017. During the last 2 years, *Teledorsagia* and *Trichostrongylus* accounted for an increased portion of the population. Results indicate that while triple treatment and rotational grazing in this region can limit egg shedding for a couple years, it quickly returns to an equilibrium based upon the ongoing control measures used.

## 85

**Comparison of efficacies of topical eprinomectin, extended-release injectable eprinomectin, and a combination of extended-release injectable eprinomectin and fenbendazole in a population of gastrointestinal nematodes of cattle with known resistance to topical eprinomectin**

Melissa George*[1], Sue Howell[1], Bob Storey[1], John Stuedemann[2], Ray Kaplan[1]. [1]The University of Georgia, Athens, GA, [2]Cold Spring Angus Farm, Comer, GA

Anthelmintic resistance in gastrointestinal nematodes of cattle is a serious problem that poses a major threat to the health and productivity of cattle. Eprinomectin is marketed as both topical and extended-release injectable formulations for cattle. This study evaluated the efficacy of an extended-release injectable formulation of eprinomectin in a herd of cattle infected with gastrointestinal nematodes that were resistant to topical eprinomectin. In spring 2013, *Haemonchus placei* and *Cooperia oncophora* that were resistant to topical eprinomectin were identified in the cow herd. In spring 2014, calves were treated with topical eprinomectin and fecal egg counts (FECs) were reduced by 77.5% and 56.1% at 2 and 4 weeks post-treatment. *Hameonchus placei* was the primary species at 2 weeks post-treatment and at 4-weeks post-treatment *Haemonchus placei, Cooperia oncophora*, *Cooperia* spp., and *Ostertagia*

were present. In contrast, extended-release injectable eprinomectin reduced FECs by 85.5% and 86.3%, at 2 and 4 weeks post-treatment, respectively, demonstrating improved efficacy of an extended-release injectable as compared to topical eprinomectin. Extended-release injectable eprinomectin reduced FECs by 94.8%, 96.5%, and 91.7% 2 months, 3 months, and 3.5 months post-treatment, demonstrating the persistent activity of this product. To evaluate the efficacy of extended-release injectable eprinomectin on parasites that survived topical eprinomectin, calves originally treated with topical eprinomectin were treated with injectable 4 weeks later, resulting in 65.5%, 80.4%, and 70.8% FEC reduction at 1, 2, and 2.5 months post-treatment. These results indicate that extended-release injectable eprinomectin may show reduced efficacy against nematodes recently pressured with topical eprinomectin. In spring 2015, a combination of extended-release injectable eprinomectin and fenbendazole reduced FECs by 97.5% and 98.4% in calves and cows, respectfully. Only *Haemonchus placei* was identified post-treatment in cows and calves. These results provide an example of how combination anthelmintic treatment and efficacy testing can be combined to provide effective parasite control.

## 86

**The effect of monthly broad-spectrum anthelmintics on intestinal parasite egg shedding in dogs**

Sandra Irurueta*, Catherine Coulter[1], Jennifer Ketzis[1]. [1]Ross University School of Veterinary Medicine, Basseterre, Saint Kitts and Nevis,

Monthly broad-spectrum anthelmintic administration to dogs is recommended as a means of decreasing egg excretion and environmental contamination with the aim of breaking the reinfection cycle. Few studies, however, demonstrate this impact. In this pilot study, the fecal egg excretion pattern of seven newly acquired dogs in a teaching kennel were followed for 4 months after a general deworming (Drontal® Plus; praziquantel/pyrantel pamoate/febantel) and then being placed on a monthly broad-spectrum heartworm preventive (Advantage Multi®; imidacloprid + moxidectin). Pens were cleaned daily and dogs were removed from their pens and walked daily. Feces were collected daily with 2-3 samples prior to commencing treatment and samples from days 1, 3, 7, 10, 14, 21 and 28 d post treatment analyzed using double centrifugation and Sheather's sugar flotation solution. When samples were positive, samples prior to and after that day were analyzed to determine when egg excretion started and ended. A subset of these was submitted to IDEXX for fecal antigen testing. The most common infection in the dogs was *Ancylostoma caninum* followed by *Trichuris vulpis* and *Toxocara canis*. Eggs disappeared from feces approximately 3 days post treatment and began reappearing near the end of the prepatent period of the respective parasite. Over all the fecal antigen and centrifugation results agreed; however, the antigen results appeared to detect infection prior to the end of the prepatent period and could distinguish passing eggs post death of the worms versus true infection. By the 3rd month of treatment only one dog continued to shed any eggs, albeit at a low level. None of the egg counts after the first round of treatment reached the level of the pretreatment counts. This pilot work demonstrates that monthly broad-spectrum anthelmintic use, in an environment with limited potential of re-exposure, is effective in breaking the infection cycle.

## 87

**Development of a method for in vivo ruminal exsheathment of *Haemonchus contortus* L3 larvae**

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The potential for preventing *H. contortus* infections through inhibition of exsheathment has been widely explored through *in vitro* testing. Very few studies have reported *in vivo* exsheathment testing of *H.*

*contortus* and only one has examined potential exsheathment inhibition. This may, in part, be due to the lack of an established validated procedure for conducting *in vivo* testing of *H. contortus* exsheathment in rumen fistulated sheep. The objective of this study, therefore, was to develop an *in vivo* exsheathment system that would: **A)** reproducibly exsheath *H. contortus* $L_3$ larvae *in vivo* and **B)** minimize parasitic infections in the fistulated animals. Multiple rumen capsule configurations as well as incubation times were tested. The final containment capsule for larvae was designed using a 3.8 cm piece of Tygon® tubing (ID 9.5 mm, OD 14.3 mm) capped at each end with an 8 µm Nunc™ Cell Culture Insert. Suspension of the capsule for eight hours in rumen of four fistulated sheep resulted in exsheathment rates of 82 ± 1%. During the testing of these capsules no significant infection of the sheep occurred. This method provides investigators the opportunity to validate findings from *in vitro* assays in a whole animal model.

## 88

***Ostertagia ostertagi* infection upregulates CD23 in abomasa and draining lymph nodes in cattle.**

Wenbin Tuo*, Pooja Sharma, Arunraj Rajendrakumar. USDA/ARS, APDL, Beltsville, MD

Ostertagiosis in cattle is caused by *Ostertagia ostertagi* which is highly endemic in temperate regions worldwide. Elevated parasite-specific IgE levels are correlated with host protection in infected animals. However, bovine CD23, the low affinity receptor for IgE, has never been characterized in cattle infected with *O. ostertagi*. CD23 is a C-type lectin and is expressed by both epithelial cells of the gastrointestinal tract and immune cells and plays a role in immune regulation and IgE transport/antigen-capture across the gastrointestinal epithelium. The present study characterized multiple bovine *CD23* transcripts and investigated *CD23* expression in the abomasal fundus and pylorus and draining lymph nodes in cattle uninfected or experimentally infected with *O. ostertagi* for 3, 5, 7 and 9 days. Infection caused severe abomasal mucosal pathology and increased draining lymph node weight and abomasal content pH. Five bovine *CD23* transcripts, as a result of possible differential mRNA splicing, were PCR-amplified from reversed transcribed cDNA and sequenced. All sequences (*CD23-X2, -X5, -X6, -X8*) exhibited putative transmembrane domains except for *CD23-X7*. Quantitative RT-PCR (qPCR) analysis of cDNA of draining lymph nodes, fundus and pylorus from *Ostertagia*-infected and uninfected cattle revealed that *CD23-X2, -X5*, and *-X8* expression was increased ($P<0.05$) in all 3 tissues of infected animals, whereas *CD23-X6* was elevated in fundus and pylorus, but not in draining lymph nodes in infected animals. Interestingly, *CD23-X7*, the transmembrane domain-free soluble variant, was decreased ($P<0.05$) in draining lymph nodes, and its expression in the abomasum was unaffected by infection. In addition, *IL-33*, a Th2 cytokine gene, was upregulated in all 3 tissues of the infected animals. The results suggest that upregulated CD23 in abomasal mucosa may be involved in binding to and transporting IgE-antigen complexes across the gastrointestinal epithelium for antigen presentation, contributing to overall host immunity.

## 89

***Ancylostoma caninum* nicotinic receptor, ACR-16, as a potential drug target for new anthelmintics.**

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Nematode infections pose a significant human and animal health challenge globally. Over 1 billion humans are infected annually while the cost to animal production is estimated at >$11 billion dollars *per anum.* Resistance of nematode parasites to anthelmintic drugs has become an extremely important issue worldwide. *Ancylostoma caninum* is a species of hookworm that poses a significant zoonotic threat as well as a general health concern to canine populations worldwide. In adult dogs the clinical presentation of hookworm infection is predominately melena and anemia. Lactogenic transmission is the primary route of infection between the mother and the pups. Symptoms of infection in young pups occur rapidly and are often fatal. In this study we cloned the nicotinic acetylcholine receptor, ACR-16, from *A. caninum*. ACR-16 is a relatively conserved acetylcholine receptor across nematode species. We cloned ACR-16 into pTB207 for expression in *Xenopus laevis* oocytes. We achieved functional expression when ACR-16 was combined with the ancillary protein RIC-3 from *Ascaris* suum. Using two-electrode voltage-clamp electrophysiology we observed robust inward currents in response to acetylcholine. Interestingly, preliminary data suggest that the *A. caninum* ACR-16 receptor does not desensitize as quickly as those from either *A. suum* or *C. elegans*. The information gathered from this study could be used therapeutically in identifying the more effective treatments for L3 and adult *A. caninum* in adult dogs and puppies.

## 90

**Does a potential endocytic motif in the calcium activated potassium channel SLO-1 of clade III nematodes affect its localization and function?**

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Emodepside is a relatively new anthelmintic compound, and the only octadepsipeptide currently available. It has recently been shown that emodepside acts directly at SLO-1 potassium channels but it is not clear if its mode of action is the same across all species of nematode. This may be due to a different subcellular localization of SLO-1 between species. A potential endocytic di-leucine motif has been identified in the C-terminal domain of the SLO-1 channel of clade III nematodes that is absent from those of clade V nematodes. In order to determine the relevance of this potential signal we have mutated the di-leucine motif from the *slo-1* sequence of the clade III parasite *Brugia malayi*, and inserted a similar motif into the sequence of the clade V parasite *Haemonchus contortus*. We have expressed epitope-tagged versions of the wild type and mutated SLO-1 channels in mammalian cell lines. To observe localization of the parasite channels *in vivo* we have created plasmids containing the *C. elegans slo-1* promoter to allow expression in *C. elegans slo-1* knockout worms. In addition, a truncated form of SLO-1 containing another potential endocytic motif (YxxÆ) has been identified. In order to visualize the effects of this motif on the trafficking of membrane proteins in vivo we have engineered the YxxÆmotif of the truncated *slo-1* sequence into a novel reporter protein expression system. This consists of expressing an mCherry:CD9 fusion protein under the control of the muscle-specific *myo-3* promoter. Sequences encoding potential trafficking motifs will be inserted into the C-terminal intracellular domain of the fusion protein. Acquiring a greater understanding of localization and function of SLO-1 channels between specific species of parasitic nematode, will further our understanding of the mode of action of emodepside.

## 91

### A Targeted Gene Knockdown System in *Cryptosporidium parvum*

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*Cryptosporidium parvum* is a zoonotic protozoan that can cause a life-threatening gastrointestinal syndrome in children and in immunocompromised adults. Currently, the only approved drug for treatment of *Cryptosporidium* infections in humans is nitazoxanide, but it is not effective in immunocompromised individuals and in children with malnutrition. This is compounded by the lack of genetic methods for studying and validating potential drug targets in the parasite. Therefore, in this study, we endeavored to adapt the use of phosphorodiamidate morpholino oligomers (morpholino) antisense approach to develop a targeted gene knockdown assay for use in *C. parvum*. We show that morpholinos, at non-toxic concentrations, are rapidly internalized by both *C. parvum* and host cells (HCT-8), and distribute diffusely throughout the cytosol. Using morpholinos to separately target *C. parvum* lactate dehydrogenase (CpLDH) and putative arginine n-methyltransferase (CpAMT) genes, within 36 h of *in vitro* culture, we achieved over 10-fold down-regulation of the respective encoded proteins in *C. parvum*. Pursuant to this, we observed that knockdown of CpLDH produced a dramatic reduction in intracellular growth and development of *C. parvum* by 56 h of culture. On the other hand, CpAMT knockdown did not appear to have any effect on parasite growth, but nevertheless, provided the proof-of-principle that the vivo morpholino knockdown assay in *C. parvum* was consistent. Together, our findings present a gene regulation approach for interrogating gene function in *C. parvum in vitro*, and further provide genetic evidence for the essential role of CpLDH in fueling the growth and development of intracellular *C. parvum*.

## 92

### Use of *Dirofilaria immitis*-infected and uninfected canine blood to determine mosquito-feeding preference

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Recent data in the field of human malaria indicate that mosquitoes are more attracted to persons infected with malaria, and chemical by-products of infection can be detected in the malaria-infected person's breath. Given the co-evolutionary relationship between mosquito vectors and *Dirofilaria immitis*, we hypothesized that dogs infected with heartworm may emit and/or secrete cues which make them more attractive to mosquitoes. To test this hypothesis, we began by determining if mosquitoes preferentially fed upon the blood from *D. immitis* infected dogs compared to dogs never infected with *D. immitis*. Each trial consisted of ~400–500 unfed, uninfected *Aedes aegypti* mosquitoes (mix of male and female) housed in a screened cage that were provided with two canine blood sources simultaneously. Each blood sample was collected in EDTA: one vial containing whole blood from a dog with an active *D. immitis* infection and the other vial containing whole blood from a dog that has never been exposed to *D. immitis*. Vials were covered with parafilm to allow for feeding, and then warmed with body-heat prior to placement on the top of the mosquito cage. Mosquitoes were observed and allowed the opportunity to feed for 5 minutes; any mosquito landing at the opening of either vial was categorized as either fed/infected or fed/uninfected. An unpaired t-test was performed and statistical significance assigned at p d 0.05. Currently 130 separate trials have been performed with a total of 294 mosquitoes feeding upon *D. immitis* infected blood and 197 feeding upon uninfected blood (p=0.006). These findings suggest the

presence of a substance in the blood of *D. immitis* infected dogs that serve as an attractant for mosquitoes, which may play a future role in the diagnosis and prevention of canine heartworm infection.

## 93

**Characterization of the effect of tetracycline antibiotics on the endosymbiont *Wolbachia* during canine heartworm treatment**

Molly Savadelis*, Katherine Day, Michael Dzimianski, Andrew Moorhead. University of Georgia, Athens, GA

The American Heartworm Society recommends the use of monthly macrocyclic lactone, the 3-dose protocol of melarsomine dihydrochloride, and 28 days of 10 mg/kg doxycycline BID for the treatment of canine heartworm disease. Doxycycline is administered to reduce the concentration of the endosymbiotic bacteria *Wolbachia* within all life-stages of *Dirofilaria immitis.* With past price increases and fluctuating availability of doxycycline, many veterinarians have switched to another tetracycline antibiotic, minocycline, as a more affordable alternative to doxycycline. While minocycline has been shown to reduce the concentration of *Wolbachia* in *Onchocerca gutturosa in vitro*, this antibiotic has not been evaluated against *D. immitis* during canine heartworm treatment. In this clinical trial, we evaluated the ability of doxycycline and minocycline at various dosages to reduce the concentration of *Wolbachia* in circulating microfilariae during canine heartworm treatment. Dogs were randomized according to enrollment to receive 10 mg/kg doxycycline, 5 mg/kg doxycycline, 10 mg/kg minocycline, or 5 mg/kg minocycline for 28 days BID. All dogs received monthly ivermectin + pyrantel and 2.5 mg/kg melarsomine on study days 60, 90, and 91. Blood samples were collected weekly throughout the tetracycline treatment and monthly thereafter. The concentration of circulating microfilariae and heartworm antigen was evaluated by standard procedures. Microfilariae were filtered from whole blood and stored at -20°C in 250µl of PBS. DNA was isolated from filtered microfilariae using the Qiagen DNeasy® Blood & Tissue Kit. qPCR was performed utilizing Taqman® probes for the *Wolbachia ftsZ* and *D. immitis* 18S rDNA genes. Preliminary data indicate that the use of minocycline and doxycycline in combination with ivermectin + pyrantel can successfully eliminate circulating microfilariae. No serious adverse events were reported during adulticidal treatment. Molecular work is ongoing and will indicate the ability of minocycline and doxycycline to reduce *Wolbachia* concentrations in microfilariae throughout treatment.

## 94

**Viability of cryopreserved *Dirofilaria immitis* microfilariae**

Christopher Evans*, Andrew Moorhead, Bobby Storey. University of Georgia, Athens, GA

The study of canine heartworm (*Dirofilaria immitis*) requires the ready availability of microfilariae (mf) from a vertebrate host, which can then be raised to subsequent life cycle stages. Research into the characteristics and mechanisms of anthelminthic resistance requires the study of multiple heartworm isolates, and maintaining patent laboratory infections of every isolate becomes prohibitively expensive and impractical. Maintaining cryopreserved mf samples that retain their infective viability allows the propagation of these isolates when needed without the continual maintenance of laboratory infections. If cryopreservation is to be used for maintaining a repository of parasites, the viability of mf following the thawing procedure needs to be characterized. In this study, we compare the viability of cryopreserved heartworm mf against non-preserved controls by measuring motility through the Worminator analysis system. The viability of mf from a known anthelminthic-susceptible isolate was also compared to a macrocyclic lactone-resistant isolate. Cryopreserved mf of both isolates demonstrated reduced motility

compared to non-preserved controls ($p < 0.00014$). No significant difference was observed between control mf of either strain ($p = 0.55$), however cryopreserved mf of the susceptible strain were found to be less motile than those of the resistant strain ($p = 0.001$). Attempts to reconstitute mf in uninfected blood and feed to permissive mosquitoes have so far been yielded no third-stage infective larvae. These data suggest that, using conventional methods, cryopreserved mf do not seem to retain their viability after thawing, and interestingly, differences appear to exist between isolates. In order to successfully maintain a repository of preserved parasites, modifications will need to be made to existing cryopreservation protocols to minimize the effects of the procedure on parasite viability allowing for more accurate and representative studies on mf and subsequent stages.

## 95

**Novel mRNA localization technique to visualize drug target expression in *Parascaris equorum***

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Understanding the interaction of drugs and their receptors is key to understanding mechanisms of drug action and resistance. There is a gap in our understanding of localization of drug receptors in the various tissues of nematodes. Current techniques such qPCR, IFA and IHC may not allow for *in situ* visualization or may suffer from the absence of readily available nematode specific reagents for study. We present a novel *in situ* mRNA localization technique that allows for the detection of single mRNA molecules in formalin fixed paraffin embedded nematode tissue. The assay is highly specific and sensitive, and involves probe binding to target mRNA sequence, followed by the amplification of signal by multiple sequential binding of molecules to the probe. We demonstrate the application of this technique in strengthening our understanding of ML resistance in the nematode *Parascaris*

## 96

**Insights into the Impact of Spurious Eggs on Nematode Infection Status in Field Dogs: Percent Agreement of Fecal Dx (Hookworm, Ascarid, and Whipworm) to Egg Flotation Observations**

David Elsemore*. IDEXX Laboratories, Inc., Westbrook, ME

Egg detection by fecal flotation is the standard method to determine the presence of a nematode infection. Recent reports have documented the possibility that spurious eggs may lead to an incomplete picture of actual infection. A field population of dogs will include many variations of infection status and egg exposure that may directly impact the agreement between antigen detection and egg observation. To explore this diversity, percent agreement between Fecal Dx antigen tests and egg flotation results were compared. A data set of 22,513 hookworm, ascarid, or whipworm egg positive samples with accompanying nematode antigen results was assembled from dog samples submitted to the IDEXX Reference Laboratories during 2016. Percent agreement of antigen to egg was compared by age range (1 to 120 months). A significant decrease in percent agreement was observed for older dogs with ascarid egg observations. The decrease in percent agreement by age was not observed for hookworm or whipworm. Fecal flotation observations of Eimeria, strongyles, or Anoplocephela indicate spurious parasites most likely introduced into the dog by coprophagy. Detection of these parasites allowed separation of the field population into a group where the likelihood of coprophagic behavior was greater. ELISA agreement to hookworm eggs is significantly lower for this group. The difference is subtler but still detectable for ELISA agreement to ascarid and whipworm especially at lower egg counts.

## 97

**Fecal survey for internal parasites of cats in eastern Virginia**

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Cats are infected by a variety of internal parasites, some of which are zoonotic. There are a limited number of published surveys of parasite prevalence in cats in the U.S., but there are no extensive surveys of cats in Virginia. Therefore, the aim of this study was to perform a large-scale survey of cats, including animal shelter and feral cats, to determine prevalence of internal parasites in this area. Fecal samples were collected from four different eastern Virginia counties between July 2016 and March 2017. Samples were examined for parasites using a zinc sulfate centrifugal fecal flotation procedure and the MERIFLUOR® *Cryptosporidium/Giardia* direct immunofluorescent assay (IFA). We examined 724 unique cat samples and overall prevalence was calculated for each parasite species found. At least one parasite species was identified in 46% of samples. Parasites identified include *Giardia duodenalis* (12% centrifugation flotation and IFA combined), *Toxocara cati* (26%), *Cystoisospora felis* (10%), *Cystoisospora rivolta* (11%), *Aonchotheca putorii* (2%), *Eucoleus aerophilus* (4.1%), *Dipylidium caninum* (0.6%), *Taenia taeniaeformis* (0.8%), *Spirometra mansonoides* (1.2%), *Ancylostoma sp.* (5%), *Cryptosporidium sp.* (1 % IFA only), *Toxoplasma -like- oocyst* (0.3%) *and Toxascaris leonina* (0.13%). *Toxocara cati* was the most common parasite found in all locations with a prevalence of up to 58% in cats in a Trap-Neuter-Release program. The results of this survey confirm that a variety of helminth and protozoan parasites are present in Virginia cats and the most commonly detected parasite was the zoonotic helminth *T.cati.*

## 98

**Demonstration of the Specificity of the Fecal Dx (Hookworm, Ascarid, and Whipworm Antigen) Assays**

Jinming Geng*, Rita Hanna, David Elsemore. IDEXX Laboratories, Inc., Westbrook, ME

Detection of adult nematode antigen by the Fecal Dx tests is a fundamentally different way to evaluate infection from the observation of nematode eggs by fecal flotation methods. The detection of secreted/excreted proteins is advantageous because antigen is available throughout the adult life cycle including the prepatent periods when eggs are not available for enrichment. Detection of antigen requires a much smaller amount of fecal material (0.2 g) and therefore may not be negatively impacted, as are flotation assays, by small sample amounts. Spurious eggs are also a confounding factor for flotation assays. An egg may be ingested and passed through a dog or a cat. Egg enrichment procedures may correctly identify the egg in the sample, but it may not indicate an infection. In light of the potential complexity in field animal's true infection status, it is important for the Fecal Dx antigen tests to be very specific to correctly determine infection in the cases where eggs are not observed and to provide additional insight into possible spurious eggs that may be false-positive. To this end, we have evaluated the specificity of the ascarid, hookworm, and whipworm Fecal Dx tests. Homogenates of whole adult nematodes were tested on each assay and demonstrated detection of each nematode homogenate by the cognate antigen test. Fecal samples from 100 specific-pathogen-free (SPF) dogs were tested on all three antigen tests. Presence of antigen was not detected for the SPF dogs. Finally, Fecal Dx results from 2016 testing at IDEXX Reference Labs were evaluated. The agreement of negative antigen results to egg negative field samples was 98% for hookworm and whipworm and 99% for ascarids.

## 99

**Descriptive findings from the analysis of fecal egg counts from beef cattle of the prairie provinces of western Canada between 2012 and 2014**

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This study was conducted toevaluate the prevalence and burden of gastrointestinal nematode (GIN) in beef cattle of the western Canadian prairie provinces between 2012 and 2014.Fresh fecal samples were collected from cow-calf operations from cows, calves and replacement heifers. Individual fecal egg counts (FEC) were performed using a modified Wisconsin sugar flotation technique. Gastrointestinal nematode eggs were identified based on morphology as a strongylid type and reported as eggs per 3 grams of feces (EP3G). Prevalence and burden were estimated using generalized estimating equations, accounting for clustering by herd.A total of 4,226 fecal samples were collected from 240 herds where 4to 57 samples (median 20, IQR 6) were collected from each herd. The prevalence of strongylid type egg positive samples overall was 76% (95% CI 75-78). The predicted prevalence was 72% (95% CI 68-77) in cows, 80% (95% CI 75-86) in calves and 75% (95% CI 69-82) in replacement heifers. The mean strongylid type EP3G was 14.3 (95% CI 12.9-15.6). The predicted mean strongylid type EP3G was 13.2 (95% CI 12.0-14.4) in cows, 19.3 (95% CI 17.1-21.5) in calves and 10.9 (95% CI 9.6-12.4) in replacement heifers. Results from these studyprovide current information on GIN prevalence and burden in beef cattle from the western Canadian prairie provinces. Comparable literature is scarce. In light of emerging anthelmintic resistance and known production impacts of GIN in cattle, the results found here highlight the need for further epidemiologic studies of GIN in beef cow-calf operations in western Canada.

## 100

**Phylogenetic Analysis and gis mapping of *Rhipicephalus* species of Ixodid Ticks of Cattle and Buffalo of District Eshawar Pakistan**

Muhammad Imran Rashid*, University of Veterinary and Animal Sciences, Department of Parasitology, Lahore, Punjab, Pakistan

Accurate identification of tick species is vital for any tick-associated research. Firstly, we identified the ticks with microscopy and then we optimized polymerase chain reaction (PCR) to discriminate various species of *Rhipicephalus,* targeting the second internal transcribed spacer (ITS2) region. In the present study, a total of 695 *Ixodid* ticks (351 cattle and 344 buffalo) were randomly collected from different body parts of each cattle (n = 50) and buffalo (n = 50) of district Peshawar. All the ticks were morphologically identified through stereomicroscopy. Out of 695, 351 ticks collected from cattle, the most prevalent were *Rhipicephalus* 194 (48.5 %*)* followed by *Haemaphysalis* 69 (17.25 %), *Hyalomma* 41(10.25 %), *Dermacentor* 32 (8 %), *Amblyomma* 15 (3.75 %) while in buffalo, the most prevalent of ixodid ticks species were *Rhipicephalus* 173 (43.25 %) followed by *Haemaphysalis 82* (20.5 %), *Hyalomma* 54 (13.5 %), *Dermacentor 26* (6.5 %)*, Amblyomma 9* (2.25 %). Tick infestation was statistically significant ($p<0.00$) in females of both species in comparison to male of cattle and buffalo. Among all the species identified through microscopy, species of *Rhipicephalus* were subjected to molecular identification through PCR. DNA was extracted from 100 ticks through phenol-chloroform method and 10 samples were identified through PCR and sequenced through ABI sequencing (Singapore). Phylogenetic analysis was performed through Mega 7. Phylogenetic analyses of the *ITS-2* sequences and morphological characters datasets revealed that our sequences resembled to Chinese and Mauritius isolates.

## 101

**Prevalence of *Toxoplasma gondii* in mourning doves (*Zenaida macroura*) from eastern Tennessee**

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*Toxoplasma gondii* (*T. gondii*) is the most successful parasite given its ability to infect a wide host range including humans, other mammals, and birds. It is estimated that about one third of humans are infected with the parasite however this statistic varies depending on geographical locations throughout the world. Humans are infected via ingestion of tissue cysts in undercooked meat or by ingestion of oocysts that are shed by infected felids. Multiple game bird species are regularly hunted and ingested by humans in North America and may represent a zoonotic risk. To date, scarce information is known about the prevalence and genotypes of *T. gondii* in birds. Mourning doves (*Zenaida macroura*) are most important game bird in the eastern United States; however, there are no previous studies on the prevalence of *T. gondii* in mourning doves and only few studies are present in other Columbiformes. The aim of this study was to test hunter-harvested mourning doves for *T. gondii*. We collected 197 hunter-harvested Mourning dove brain tissue samples from a Wildlife Management Area in Knox County, Tennessee, USA. Portions of each brain were DNA extracted followed by DNA amplification by PCR using previously published primers that amplify the 529-bp repeat element of *T. gondii*. Of 197 dove brain samples tested, two (1%) birds were PCR and sequence positive for *T. gondii*. Further studies are needed to elucidate the role that other game and non-game bird species play in the transmission of *T. gondii* and the zoonotic potential.

## 102

**Investigation of the prevalence and distribution of *Echinococcus multilocularis* in wild canids in Ontario, Canada**

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Historically, in North America, *Echinococcus multilocularis* was considered endemic in only the Arctic and north-central regions. Thus, prior to 2012, Ontario, Canada was considered free of this parasite. Since then, alveolar echinococcosis has been reported in five dogs and two non-human primates in southern Ontario. Of these cases, six had no travel history, raising concern that wild canids may be shedding eggs into the Ontario environment. To determine the prevalence, geographic distribution, and risk of infection for *E. multilocularis* in wild canids across southern Ontario, carcasses were collected from hunters and trappers across the region. From November 2015 to August 2016, 204 wild canids (183 coyotes and 22 foxes) were obtained. Rectal fecal samples collected during post-mortem were analyzed via a semi-automated magnetic capture probe DNA extraction and real-time hydrolysis PCR method for the presence of *E. multilocularis* DNA. Demographic factors (e.g., sex, weight, and body length) were recorded at the time of post-mortem. Overall, 16.2% (95% confidence interval: 11.4%-22.0%) of wild canids from the western, central, and eastern regions of southern Ontario tested positive. Using a spatial scan test, a spatial cluster of high prevalence of infection was identified (relative risk=6.86; $p<0.05$) that covered six contiguous public health units in the western and central regions of southern Ontario. The results from fitting mixed logistic regression models with a random intercept for public health unit indicated there was a high level of clustering in *E. multilocularis* carriage by health unit and that the odds of a coyote testing positive for the parasite significantly decreased with increasing

body length. However, other morphometric and demographic factors were not significantly associated with *E. multilocularis* carriage. This is the first report of *E. multilocularis* infection in wild canids in Ontario and indicates a changing epidemiological situation of the parasite in North America.

## 103

**Epidemiological risk factors and prevalence of anti-antibodies to *Neospora* spp. in donkeys from Punjab province, Pakistan**

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*Neospora caninum* is recognized as one of the most prevalent causes of abortion and neonatal mortalities in cattle. *Neospora hughesi*, the only other member of the genus, causes reproductive problems in horses. The antigens of these parasites are similar and cross reactive in most serological assays and the results are best reported as *Neospora* species when equine samples are used. There is limited data available on the prevalence of *Neospora* antibodies in donkeys worldwide. The purpose of current study was to describe seroprevalence of *Neospora* infection in donkeys from Pakistan. In this cross sectional study sera from 91 donkeys were examined from Punjab province, Pakistan to determine the prevalence of antibodies against *Neospora spp*. Antibodies to *Neospora* spp. were detected using a commercially available competitive ELISA (VMRD, Inc., Pullman, USA). IgG antibodies to *Neospora* spp. were found in 23 (25.2%) of 91 animals. Highest prevalence was seen among animals raised in contact with ruminants (27.4%) and pets especially dogs (30.7%), indicating a significant difference *(P<0.05)* in prevalence between two categories (with and without presence of domestic ruminants and dogs). Seroprevalence was significantly *(P<0.05)* higher in castrated animals (36.4%) than female (23.83%) and male (18.9%) equids. The prevalence ranged in different breeds of donkeys from 31.4% (crossbreed) to 3.7% (Shinghari breed) and in different purpose of use from 26.8% (draughting) to 12.4% (breeding). The prevalence rate was significantly *(P<0.05)* higher in female animals with history of early pregnancy loss 44.2% (19/43), and late pregnancy loss 30.6% (23/75) than that of female donkeys have had no exposure of pregnancy loss, 9.4% (9/96). Statistical analysis indicating a significant association between feeding style and protozoan infection; rearing shelter was also a significant risk factor for *Neospora* infection. No significant difference was noted among age groups and risk of *Neospora* infection.

## 104

***Sarcocystis neurona*: advances in life cycle manipulation**

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Equine protozoal myeloencephalitis (EPM) remains a significant central nervous system disease of horses in the American continents. *Sarcocystis neurona* is considered the primary causative agent of EPM and the intermediate life stages of the parasite are carried by a wide host-range including raccoons *(Procyon lotor*). Yet, to date, no one has taken a naturally derived isolate from culture of an EPM case and produced tissue cysts of the organism. We also know that tissue cysts described in marine mammals are morphologically smaller than those reported for terrestrial mammals such as raccoons. We sought to test the following two hypotheses: 1) culture-derived merozoites obtained from a clinical EPM horse

(SN-MU1) would produce tissue cysts when experimentally inoculated into raccoons, and 2) cryopreservation of tissue cysts containing bradyzoites would retain their infectivity to produce sporocysts. This study utilized culture-derived parasites of the *S. neurona* strain from a raccoon (SN-744) in addition to the equine isolate (SN-MU1). Four raccoons per inoculation group and two controls were used. Fresh and cryopreserved raccoon tissues were used to establish laboratory-reared opossum (*Didelphis virginiana*) infections, which then shed sporocyts with retained biological activity to cause encephalitis in mice. These results demonstrate that sarcocysts can be generated using *S. neurona* merozoites derived from a naturally infected horse with clinical EPM. These tissue cysts were much smaller than those produced by the raccoon isolate. Sarcocysts containing bradyzoites can be successfully cryopreserved and later thawed to initiate an infection in the definitive host. We demonstrated the life cycle can be significantly manipulated in the laboratory without affecting subsequent stage development or biological capacity. These results allow further purification of strains and artificial maintenance of the life cycle disconnected from the host's natural reproductive cycle, providing an improvement in the tools available to study *S. neuron.*

## 105

**Anthelmintic efficacy of two commercial products against equine cyathostomins (Nematoda: cyathostosminae) was examined using FLOTAC**

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Control of the cyathostomins in horses is based on the constant use of anthelmintics. However, the indiscriminate use of these products has generated resistance to benzimidazoles and more recently to macrocyclic lactones. In this sense, the objective of this study was to evaluate the efficacy of the main anthelmintic products used in the treatment of equine cyathostomins. Animals from five farms in the state of Pernambuco were treated with ivermectin (IVM) and fenbendazole (FBZ). Efficacy was determined by calculating the fecal egg count reduction at days 0, 7, 14 and 21 after treatment. Fenbendazole showed low efficacy in 100% of the studied properties, whereas IVM exhibited resistance on only 25% of the farms. Anthelmintic resistance to IVM and FBZ was identified in all horse flocks investigated; however, resistance to FBZ was consistently higher. These results clearly demonstrated the higher efficacy of IVM on most farms though high resistance to IVM was observed on one farm. The interval of deworming, inadequate or improper dosing for prolonged periods and/or non-selective dosing were factors that contributed to the anthelmintic resistance of FBZ and IVM on the studied properties.

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