

## Curriculum Vitae

*William S. Marshall, Ph.D.*

### **Title**

Senior Research Professor  
Department of Biology  
St. Francis Xavier University

### **Mailing Address**

Department of Biology  
St. Francis Xavier University  
Antigonish, Nova Scotia B2G 2W5

**Phone** (902) 867-2482 [home (902) 863-5913]

**FAX** (902) 867-3421      **e-mail** bmarshal@.stfx.ca

### **Personal Information**

Birth: April 26, 1951, Victoria BC

Citizenship: Canadian

Marital Status: Married, two children

Spouse: Penelope J. Fuller, M.D., F.R.C.S.(C.)

Outside interests: sailing, canoeing, hiking, fishing, biking, kids (active in United Church), dogs.

### **Previous Appointments**

Senior Research Professor 2016-

Full Professor 1994-2016

Chair, Dept. Biology Jan 2010 – May 2012

Dean of Science July 2005-September 2009

Chair, Dept. Biology 1999-2001

Associate Professor 1987-1994

Assistant Professor & NSERC University Research Fellow 1982-1987

Department of Biology

St. Francis Xavier University

Instructor 1981-1982

Associate 1979-1981  
Department of Ophthalmology  
Louisiana State University Medical Center , New Orleans, Louisiana

## **Education**

NSERC and Killam postdoctoral fellow 1977-1979  
Department of Zoology & Cancer Research Laboratory  
University of California at Berkeley  
Berkeley, California

Ph.D., Zoology, November, 1977  
Department of Zoology  
University of British Columbia  
Vancouver, BC, Canada

B.Sc. With honours, May, 1973  
Department of Biology  
Acadia University  
Wolfville, NS, Canada

## **Memberships**

Canadian Society of Zoologists (since 1974)  
American Physiological Society (since 1981)  
Canadian Physiological Society (since 1984)  
Nova Scotia Institute of Science (since 1988)  
Society for Experimental Biology (UK) since 1994  
Association for Research in Vision and Ophthalmology (1980-1990)  
American Society of Zoologists (1978-1993)

## **Undergraduate Teaching Experience**

Biology 499 Special Topics: Role of collagen scaffolds in skin wound healing (Evan Kotler) Autumn 2018-19

Ichthyology (Biol 306, 3 credit hours plus lab)  
Winter 2016 (enrolment 8)  
Winter 2014 (enrolment 12)  
Winter 2013 (enrolment 16)  
Winter 2012 (enrolment 12)  
Winter 2011 (enrolment 17)  
Winter 2010 (enrolment 16)

Comparative Endocrinology (Biol. 404; 3 credit hours + lab)

Winter 2012	(enrolment 11)
Winter 2010	(enrolment 10)
Winter 2002	(enrolment 8)
Winter 2000	(enrolment 2)
Autumn 1997	(enrolment 3)
Autumn 1996	(enrolment 7)
Winter 1995	(enrolment 5)
Winter 1992	(enrolment 11)
Autumn 1989	(enrolment 16)
Autumn 1987	(enrolment 15)
Autumn 1986	(enrolment 10)
Autumn 1985	(enrolment 6)

Membrane Biology (Biol. 402; 3 credit hours + lab)

Autumn 2015	(enrolment 8)
Winter 2013	(enrolment 3)
Winter 2010	(enrolment 8)
Autumn 2003	(enrolment 4)
Autumn 2002	(enrolment 3)
Winter 1999	(enrolment 3)
Winter 1998	(enrolment 3)
Winter 1997	(enrolment 2)
Winter 1993	(enrolment 6)
Winter 1990	(enrolment 2)
Autumn 1988	(enrolment 7)
Winter 1987	(enrolment 9)
Winter 1986	(enrolment 1)

Vertebrate Physiology (Biol. 304; 3 credit hours + lab)

Winter 2016	(enrolment 9)
Winter 2015	(enrolment 21)
Autumn 2014	(enrolment 24)
Winter 2013	(enrolment 28)
Winter 2003	(enrolment 41)
Winter 2002	(enrolment 42)
Autumn 2001	(enrolment 17)
Winter 2000	(enrolment 23)
Winter 1999	(enrolment 34)
Winter 1998	(enrolment 30)
Autumn 1996	(enrolment 30)
Autumn 1995	(enrolment 45)
Autumn 1994	(enrolment 17)
Autumn 1992	(enrolment 51)

Autumn 1991	(enrolment 62)
Autumn 1990	(enrolment 42)
Winter 1990	(enrolment 46)
Winter 1986	(enrolment 58)

Human Physiology (Biol 252; 3 credit hours + lab)

Winter 1995	(enrolment 150)
Winter 1993	(enrolment 106)
Winter 1992	(enrolment 128)
Winter 1991	(enrolment 108)
Autumn 1989	(enrolment 56)

Animal Biology (Biol. 201; 3 credit hours and lab)

Autumn 2015	(enrolment 119)
Autumn 2014	(enrolment 121)
Autumn 2013	(enrolment 120)
Autumn 2012	(enrolment 122)
Autumn 2011	(enrolment 141)
Autumn 2003	(enrolment 123)
Autumn 2002	(enrolment 109)
Autumn 2001	(enrolment 99)
Autumn 2000	(enrolment 121)
Autumn 1999	(enrolment 110)
Autumn 1998	(enrolment 90)
Autumn 1997	(enrolment 88)
Autumn 1996	(enrolment 102)
Autumn 1995	(enrolment 95)
Autumn 1994	(enrolment 148)

Introductory Biology (Biol. 100; 6 credit hours + lab)

Autumn 1987 - Spring 1988	(enrolment 122)
Autumn 1988	(enrolment 128)

**Graduate Teaching**

Biol 581 Special Topics: section on biometrics (2018, enrolment 2)

Biol 504 Advanced topics in vertebrate physiology Winter 2012  
(MacLellan)

Biol 504 Advanced topics in vertebrate physiology Winter 2010  
(McLachlin)

Biol 504 Advanced topics in vertebrate physiology Winter 2002 (Noel)

**Administrative Experience**

## **Academic**

Member, ad hoc committee to select Assoc. V.P. Research, 2015  
Member, ad hoc Research Integrity committee on a case of academic impropriety 2014  
Chair, JBB Occ. Health & Safety Committee (2013-2017), by appointment  
Chair, Department of Biology, 2010-2012, by appointment  
Member, Research Advisory Council, NSHRF, 2008-2017  
Dean of Science, 2005-2009, by appointment  
Member, Canadian Association of Deans of Health Professions *ex officio* (2005-9)  
Member, Nova Scotia Academic Health Council *ex officio* (2005-9)  
Member, Canadian Assoc. Deans of Science *ex officio* (2005-9)  
Member, Atlantic Assoc. Deans of Science *ex officio* (2005-9)  
Member, Atlantic Environmental Sciences Network Board (2005-9)  
Chair of Department, 1999-2001, by appointment  
Chair, StFX Faculty Development Committee, 2000-2002, by election  
Chair, St. F.X. Animal Care Committee (2001), by appointment  
Member, Biology Faculty evaluation committee (1995-2003), by election  
Member, St.F.X. Animal Care Committee (1998-2000; 2002), by invitation  
Coordinator, Physics Department Review (1999), by invitation  
APICS Aquaculture representative for St. F. X. '97-'99, by appointment  
Canadian Foundation for Innovation, St. F.X. Task Force '97-'98, by appt.  
Ad Hoc Committee to develop Research statement 1995, by appointment  
Committee on Research ethics 1994, by election  
James Chair Selection Committee 1992-4, by appointment  
University Council for Research 1992-4, by election  
Health plan Assessment Committee '91-'92, by appointment  
Rank & Tenure Committee 1989-92, by election  
St. F. X. & APICS Animal Care Committee 1988-90; 1992-95, by appt.  
P.R. rep for Biology Dept. 1992-4  
University Senate 1984-1987, by election  
Computer Services Policy Committee, 1983-1986, by election  
Nominations Committee, 1985-1987, by election  
Performing Arts Committee 1986-92, by election  
Computer Users' Committee, 1986-1989, by election  
Committee on Studies 1987-88, by election  
St.FX AUT Committee on sexual harassment '87, by election

## **Research Administration**

Member, NSERC Discovery Grants Integrative Biology Evaluation Committee (2013-2016), by appointment  
Chair, Sumner Foundation Graduate Scholarships Selection Committee (2006-15)

Chair, Cdn. Council on Animal Care Site Visit, Mount Allison U Sackville NB (2012, *declined*)

Chair, Cdn. Council on Animal Care Site Visit, Nat Res Council Halifax (Sept 2009)

Chair, Cdn. Council on Animal Care Site Visit, University of Windsor (May 2007)

Chair, Cdn. Council on Animal Care Site Visit St. Andrew's Biological Station (Sept 2005)

Member Cdn. Council on Animal Care site visit team to Bedford Inst. Oceanography and Cdn Food Inspection Agency (Nov 2002)

Symposium Organiser: Soc. Integ. Comp. Biol. USA (Toronto meeting 2003)

Invited to be Member of College to assess Canada Res. Chairs, 2001 (*Declined for family reasons*)

Chair, NSERC evaluation committee, Marine Sciences Research Lab, M.U.N. (1999)

Invited to become NSERC section leader for Life Sciences, 2000 (*Declined for family reasons*)

Member, NSERC Site visit team, Committee 30 (twice).  
     York U. and U. of T. (all 3 campuses) (1998)  
     N.S.A.C., Acadia U. and Mt. Allison U. (1997)

Chair, Working Group, NSERC Grants Selection Committees (30, 31) (2000)

Past President, Canadian Society of Zoologists (CSZ) (2000)

President, Canadian Society of Zoologists (CSZ) (1999)

1st Vice Pres., Canadian Society of Zoologists 1998

Member, NSERC Animal Physiology Grants Selection Committee (31) '96-'99

2nd Vice Pres., Canadian Society of Zoologists 1997

Member, NSERC ad hoc committee to develop apportionment formula for postgraduate scholarships envelope 1996

Member, NSERC Committee on Scholarships & Fellowships '93-'96

Member, CSZ Council '93-96

Symposium Co-organiser with John Phillips, Int. Congr. Comp. Endocrinology 1993

Chair, Local Organizing Committee, CSZ Annual Meeting 1992 at St.F.X.

Symposium Organiser, Estuaries symposium, CSZ meeting 1992

Chair, Comp. Physiol. Biochem. Section C.S.Z. 1992

NSERC Postgraduate Scholarship Selection Committee, 1985-1988

Member, APICS Animal Care Committee 1987-88

### **Host to James Chair Professors (Visiting Research Chairs)**

Hans O. Pörtner, Alfred Weniger Institut, Bremerhaven (2013)

Else K. Hoffmann, August Krogh Inst, Copenhagen (2003)

    Steve D. McCormick, University of Massachusetts (1999)

    Carole Liedtke, Case Western Reserve University (1995),

    John Phillips, University of British Columbia (1994),

    Chris M. Wood, McMaster University (1991),

    Aubrey Gorbman, University of Washington (1985),

Howard A. Bern, U. California, Berkeley (1984),

### **Nominator and host to St.F.X. Honorary Doctors**

2000 Peter W. Hochachka, Dept. Zoology, U.B.C. (Prominent Comparative Biochemist and Physiologist) Peter was awarded Order of Canada the following year.

1995 Lap Chee Tsui and John R. Riordan, University of Toronto Hosp. For Sick Children (Co-discoverers of Cystic Fibrosis Transmembrane Conducance Regulator, the ion channel that produces CF disease)

### **Research Activities**

Project: Control of transport in epithelia

Disciplines: Epithelial transport physiology/biophysics

Location: Dept. Biol. St. Francis Xavier Univ.

Dates: November 1982 -

Collaborators:

Jason Breves, Skidmore College, NY

Scott Kelly, York University, ON

Christian Tipsmark, U. Arkansas

Trish Schulte, Zoology Dept., U.B.C.

Hans O. Portner, Alfred Weniger Institut, Bremerhaven, Germany

E.K. Hoffmann, August Krogh Instit., U. Copenhagen

T.D. Singer, U. Waterloo.

S. McCormick, US Fish & Wildlife, & University of Massachusetts

C. Higgins, Oxford U. Dept. Clinical Biochemistry, U.K..

P. Verboost, G. Flik, U. Nijmegen, Animal Physiology, Netherlands

C. Wood, McMaster University, Biology

C. Liedtke, Case Western Reserve U., Dept Pediatrics, U.S.A.

A. Midelfart, U. Trondheim, Ophthalmology Dept, Norway

D. Idler, M.U.N. Oceans Sciences Research Center

J. Hanrahan, McGill University, Dept. Physiology

### **Active Research Grants**

Source: Natural Sciences and Engineering Research Council (NSERC)

Designation: NSERC operating grant

Title: "Control of ion transport by epithelia"

Principal Investigator: W.S. Marshall

Amount: \$28,000 p/a April 2017-April 2022

## **Grants Applications under consideration (none)**

## **Previous Research Grants (external peer-reviewed)**

Source: Natural Sciences and Engineering Research Council (NSERC)

Designation: NSERC operating grant

Title: "Control of ion transport by epithelia"

Principal Investigator: W.S. Marshall

Amount: \$25,000 p/a April 2009-April 2017

Source: Natural Sciences and Engineering Research Council (NSERC)

Designation: NSERC operating grant

Title: "Control of ion transport by epithelia"

Principal Investigator: W.S. Marshall

Amount: \$48,800 p/a April 2004-April 2009

Source: Natural Sciences and Engineering Research Council (NSERC)

Designation: NSERC operating grant

Title: "Control of ion transport by epithelia"

Principal Investigator: W.S. Marshall

Amount: \$48,400 p/a April 2000-April 2004

Burroughs Wellcome Foundation

Designation: Visiting Professorship in Biomedicine

Title: Proposal for Prof. John Hanrahan as BWF visiting professor

P.I.: WS Marshall (grant monies went to Visiting Professor)

Amount: \$5,000 (US) March 2002

Source: NSERC

Designation: Equipment Grant

Title: "Vapour Pressure Osmometer"

Principal Investigator: W.S. Marshall

Amount: \$9,900 2003

Source: NSERC

Designation: Equipment Grant

Title: "Microplate reader"

Principal Investigator: L. Graham

Coinvestigators W.S. Marshall, M. Galway

Amount: \$42,000 2001



Source: Canadian Foundation for Innovation (CFI)  
Designation: Equipment Grant  
Title: "Completion of Advanced Microscopy Facility"  
Principal Investigator: W.S. Marshall  
Co-Investigators: J. Buckland-Nicks, D. Garbary, M. Galway  
Amount: \$183,500 April 2000  
(ACOA matched \$183,500 and University \$91,750 for a total of \$458,750)

Source: NSERC  
Designation: Equipment Grant  
Title: "Ultra low temperature freezers"  
Principal Investigator: W.S. Marshall +8 coapplicants  
Amount: \$13,500 1995

Source: NSERC  
Designation: NSERC/DFO Science Subvention Grant  
Title: "Transport of organic solutes by fish gills"  
Principal Investigator: W.S. Marshall  
Amount: \$10,000 April 1994-April 1996

Source: NSERC  
Designation: NSERC operating grant  
Title: "Control of ion transport by epithelia"  
Principal Investigator: W.S. Marshall  
Amount: \$44,000 p/a April 1993-April 1999

Source: NSERC  
Designation: Equipment Grant  
Title: "Micropipet puller and micropositioner"  
Principal Investigator: W.S. Marshall  
Amount: \$13,850 1993

Source: NSERC  
Designation: International Scientific Exchange Award  
Title: "A. Midelfart visit: corneal epithelial transport"  
Principal Investigator: W.S. Marshall  
Amount: \$2,913 1993

Source: NSERC  
Designation: Equipment Grant  
Title: "Patch Clamp"  
Principal Investigator: W.S. Marshall

Amount: \$22,500 1991

Source: NSERC  
Designation: Conference Grant  
Title: Adaptation to the Estuarine Environment  
Principal Investigator: W.S. Marshall  
Amount \$9,000 1992

Source: NSERC  
Designation: Equipment Grant  
Title: "Gas mixing Pump"  
Principal Investigator: W.S. Marshall  
Amount: \$16,780 1989

Source: NSERC  
Designation: operating grant (A3698)  
Title: "Control of ion transport by epithelia"  
Principal Investigator: W.S. Marshall  
Amount: \$35,000 p/a April 1987-April 1990

Source: NSERC  
Designation: Equipment Grant E2739  
Title: "Liquid Scintillation Counting System"  
Principal Investigator: W.S. Marshall  
Co-Investigators: C.A. Lessman and M. Weisbart  
Amount: \$36,457 1987

Source: NSERC  
Designation: Equipment Grant EQP0038081  
Title: "Microscope Nomarski Optics"  
Investigators: D. Garbary, C.A. Lessman and W.S. Marshall  
Amount: \$7,472 1988

Source: NSERC  
Title: "Control of ion transport by epithelia"  
Principal investigator: Wm. S. Marshall  
Amount: \$30,138 p/a; April 1985 - April 1987

Source: NSERC Equipment Grant  
Title: "Microscope photometer"  
Principal Investigator: Wm. S. Marshall  
Co-investigator: J.W.D. Garbary, Ph.D.  
Amount: \$21,000 1986

Source: NSERC Operating grant  
Title: "Control of ion transport by epithelia"  
Principal investigator: Wm. S. Marshall  
Amount: \$28,938 p/a; April 1982-April 1985

Source: Canadian National Sportsmen's Fund  
Title: "Cellular models for effects of acid precipitation on ion balance in fish"  
Principal investigator: Wm. S. Marshall  
Amount: \$10,000; 1984

Source: Canadian National Sportsmen's fund  
Title: "A cellular model for the effects of acid precipitation on ion balance in fish"  
Principal investigator: Wm. S. Marshall  
Amount: \$9,500; 1983

Source: NSERC - equipment grant  
Title: "Four channel oscillographic recorder"  
Principal investigator: Wm. S. Marshall  
Amount: \$16,964.00, 1983

### **Other Grants**

The University Council for Research provides support for one undergraduate student in my lab per year at approximately \$1,100 per student. Total since 1983 is approximately \$25,000  
I usually apply to HDRC for a summer research student. If awarded, these pay approx. \$1,100 per year. Total since 1983 is approx. \$16,000.

### **Academic Awards & Appointments**

University Research Award (St Francis Xavier University) 2005  
NSERC Representative for St. Francis Xavier University (2002-05)  
Adjunct Professor, Dalhousie U. Pharmacology 1995-  
Adjunct Professor, Atlantic Vet. School, Anatomy & Physiology 1993-  
NSERC Univ. Research Fellowship renewal (1985-1992)  
URPTA, St. F.X. Univ. (1982-2016) (A university stipend paid to active researchers)  
NSERC Canada University Research Fellowship (1982-1984)  
Killam postdoctoral fellowship (1977-1979)  
NSERC Canada postdoctoral fellowship (1977-1979)  
NSERC Canada postgraduate scholarships (1973-1977)  
M.C. Smith scholarship in marine biology (1972)

Dean's list scholarship (1970-1971)  
B. Smith Memorial Scholarship (1970-1971)  
Dean's list scholar (1969-1973)

### **Editorships**

Associate Editor, *Journal of Experimental Zoology*, CPB section 2002-2005

Member, Editorial Board, *Comparative Biochemistry & Physiology* 2001-3; 2004-9

Associate Editor for "*Estuaries*" (1992-1995)

### **Research Reviews**

Reviewer for Journal articles (about 15 per year):

Frontiers in Physiology

Comparative Biochemistry and Physiology

Physiological and Biochemical Zoology

Fish Physiology & Biochemistry

Journal of Experimental Zoology

American Journal of Physiology

Canadian Journal of Zoology

Journal of Experimental Biology

Canadian J. Fisheries Aquatic Sciences

Journal of Morphology

General and Comparative Endocrinology

Estuaries

Zoological Science

Acta Physiologica

North American Journal of Aquaculture

Plos One

Marine Biology

Biochimica Biophysica Acta

Transactions of the American Fisheries Society

Journal of Comparative Physiology

### **Grant and other reviews (3-4 per year)**

NSERC Operating Grants, Discovery Grants (1988-2014 (1-3 per year))

NSERC Steacie Memorial Fellowship (1987, 2002)

Order of Canada, P.W. Hochachka candidacy (2001)

Hong Kong NSF Research Grant Review (2000, 01, 05, 07, 09)

NERC (UK) Research Grant review (1996, 2009)

NSERC Strategic Grant Review (1996)

Research Corporation Grants Program (1988)

NSF Grants Program (1984, 85, 95, 2000, 05, 06, 07, 13)  
 DFO Subvention Grant Program (1986)  
 Fish Physiology Vol. XII, XIV, XXXIV (1987; 94; 2013)  
 Academica Sinica Investigator Award (PP Hwang) 2010  
 Physiology of Fishes 4<sup>th</sup> Edition (reviewed 2017)

**External examiner of Theses**

York University Ph.D. Dennis Kolosov (2016)  
 University of Ottawa, Ph.D., Yosuke Kumai (2013)  
 Memorial University of NF, M.Sc. Mr. Stephen Winsor (2000)  
 University of Nijmegen Ph.D., Dr. Peter Klaren (1995)  
 University of British Columbia Ph.D., Dr. R.A. Harris (1992)  
 Dalhousie University Ph.D. Dr. Kurt Gamperl (1992)  
 University of British Columbia Ph.D. Dr. Bruce Tufts (1987)

**Member of Graduate Thesis Committees**

Member, supervisory committee Alex Young M.Sc.  
 Member, Ph.D. examination committee for Qian Ping Lee  
 Dept. Pharmacology, Dalhousie Univ., 1999

**Thesis Supervisor (No Ph.D. program available)**

**Master's Students**

<b>Name</b>	<b>Degree</b>	<b>Year</b>	<b>Thesis Topic</b>	<b>Current Occup.</b>
Garg, D.	M.Sc.	1991	Intracellular pH and control of Cl <sup>-</sup> cells by alpha adrenergic receptors.	Comp. Sci.
MacLellan, A.	M.Sc.	2015	Focal Adhesion Kinase (FAK) Family Tyrosine Kinases Mediate Cell Volume and Ion Transport Regulation in Calu-3 Human Airway Epithelia	Dal. Medicine

**+Honours Undergraduate Students**

\*indicates co-supervision (most went through U. Calgary neuroscience)

#indicates NSERC USRA or Alberta Heritage scholarship holder

@ indicates UCR, MacLachlan or Chaisson scholarship holder,

\$ indicates Irving Mentorship Award

Name	Year	Research Topic	Progressed to:
@Fougere, Breton	2018	FAK inhibitors	In progress
@Kotler, Eric	2018	Collagen scaffolds in burn healing	In Progress
Ellen Doohan	2017	Ion selectivity tight junctions	Vet. Tech.
@Francis, Magen	2016	Cold acclimation and osmoregulation	Applying Medicine
+@Doohan, Ellen	2016	Halocline behavior in killifish	returned in year 5
+@Tait, Janet	2015	Cold acclimation and transport regulation	MSc Health Sci
Mercer, Evan	2015	Hypersaline and transport regulation	Dal. Dentistry
\$Garrow, K.	2014	WNK Kinase in Cl <sup>-</sup> secretion regulation	Unknown
Zaparilla, G.	2014	Cold acclimation ionocyte electrophysiology	MSc Economics
Heustis, A.	2013	Ocean acidification and fish behavior	M.Sc, U.N.B.
Claus, L	2013	Osmosensing in hypersaline conditions	Paramedic
#Maclellan, A.	2012	Calu-3 cells and FAK phosphorylation	MSc. St.FX
+#Malone, A.	2012	Cold acclimation in eurythermic fish	MSc Dalhousie Immunology
+#Barnes, K.	2011	Cold and anaerobiosis in killifish	MUN Medicine
+@Maclellan, A.	2010	Calu-3 cells FAK expression	returned as MSc
+Buhariwalla, H.	2010	Eurythermy in Killifish ion transport	U Ottawa Medicine
Barnes, K.	2010	Time course FAK pY407 activation	returned 2011
+Hosier, G.	2009	CFTR regulation in Calu-3 cells	MSc U. Ottawa
+#Osmond, E.	2009	FAK and intercellular junctions	MUN Medicine
+@Hovdestad, L.	2008	FAK and CFTR in volume regulation	MSc Global Health McMaster
+Goudie M.	2007	Calcium uptake in FW fish	M.Sc. Ecology U. Alberta
+#Watters K.	2007	FAK and CFTR transport regulation	Dalhousie Audiology
+Lynch, B.	2006	PTP inhibitor effects on ion transport	Radiology Tech.
+#Main, H.	2005	Focal adhesion kinase function	Dalhousie Medicine
Desta, A.	2005	Salt-Ash highway traction product	Dalhousie Engineering
Quinn, M.B.	2005	Killifish Genome project	Dalhousie Medicine

### Summer Research Students, Cont'd

#Hill A.	2004	Water calcium effects on fish	Dalhousie Dentistry
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Gilchrist M.	2004	Microhabitats in estuaries	Dalhousie Dentistry
MacIsaac M.	2004	Calcium effects on ion transport	Dalhousie Dentistry
+Strapps, C.	2004	Ectoparasite effects in killifish	Dalhousie Law School
+@Epega, A.	2003	Ion transport modulation in fish	Dr. Naturopathy
+#Lynch, E.	2003	CFTR trafficking in chloride cells	Dalhousie Education
Sers, N.	2003	Actin inactivation and transport	Dalhousie Oc. Therapy
#Knickle, K.	2002	NKCC regulation in chloride cells	Dalhousie Medicine
Lynch, E.	2002	CFTR trafficking in chloride cells	returned
+#Howard, J.A.	2002	Ion transporters in fish intestine	Dalhousie Medicine
+#Oldford, J.	2001	Phylogenetic evolution of the CFTR gene	Advanced studies in Arts
+#*Nimigan, A.	2001	Genes expressed in freezing amphibians	U. Ottawa Medicine
#Oldford, J.	2000	Nonylphenol toxicity mechanisms	returned
+Doyle, T	2000	Time course of FW adaptation	Dalhousie Dentistry
+Daborn, K.	1999	Pavement cell Cl <sup>-</sup> cell interactions...	Medical Supplies Mgr.
+#Emberley, T	1998	Transfer of Fundulus to seawater...	McMaster Medicine
+#*Gillis, A.	1998	FGF receptor expression in brain...	Dalhousie Medicine
+Luby, T.	1997	Serosal tonicity & Cl <sup>-</sup> transport...	Osteopathic medicine
+#McAlduff, D.	1997	Cadmium & Cl <sup>-</sup> transport inhibition.	M.Sc. U of T Biophysics
+DuQuesnay, R	1996	Neural control of Cl <sup>-</sup> transport...	M.Sc., Dal. Pharmacology
+#Gillis, J.	1995	Neural control of Cl <sup>-</sup> transport...	U. Western Ont. Medicine
+#*Ozol, K.	1993	Zebrin expression in primate cerebellum...	Ph.D. Calgary. Neurobiology
+#Burghardt, J.	1993	Ca <sup>2+</sup> transport by Cl <sup>-</sup> cells...	Ph.D. Alta., Ob./Gyn.
+#Whitten, C.	1992	Freshwater Cl <sup>-</sup> cell function...	Memorial U. Medicine
+Darling, P.	1991	Freshwater Cl <sup>-</sup> cell function...	Molec. Biol. Technician
+*Joshi, R.	1990	Pit connections in red algae...	Dalhousie Medicine
+#Fisher, R.	1989	Intracellular pH of Cl <sup>-</sup> cells...	Dalhousie Medicine
+Sapp, M.M.	1986	Volume regulation in erythrocytes	Dalhousie Medicine
+Gillis, M.	1986	Cytoskeleton of Cl <sup>-</sup> cells...	Dalhousie Dentistry
+Redondo, I.	1985	Acid effects on paracellular path	Res. Assoc. Pharmacology
+*McNeely, D.	1984	Kindling of seizures in rats...	Dalhousie Medicine
+MacNeil, P.	1983	Ca <sup>2+</sup> and pH effects on Cl <sup>-</sup> cells	Dalhousie Medicine

### Theses

1. BSc Hon: Marshall, W.S., 1973. The effects of salinity on the lethal temperatures of *Fundulus heteroclitus* L. and a study of some salt marsh pools. Department of Biology, Acadia University, Wolfville, N.S., Canada.

2. Ph.D.: Marshall, W.S., 1977. The functions and endocrine control of epithelial mucus secretion in the family Cottidae. Department of Zoology, U.B.C., Vancouver, Canada.

### Publications, Summary

Full papers Published & In Press:	82
Submitted:	2
In Preparation:	2

**Total citations (source: Web of Knowledge May 2019) 2217 (1989-2019), approx. 2650 for all years., h index: 24**  
**Average citations per article: 49.27**

### MOST SIGNIFICANT CONTRIBUTIONS

**bold names** are Honours undergraduates **bold underlined** are MSc students under my supervision; Underlined names are James Chair Professors; \* indicates PDFs under my supervision; {citations stats, Web of Knowledge, on peer adjudicated papers} For book chapters only, [citations, Google scholar]

#### Most significant contributions 2018 and earlier

**A.** Single-stranded tight junctions with cation conductance in fish gills were discovered almost 40 years, but their structure and regulation are unknown. The claudin protein family, specifically claudins 10-c, -d, -e and -f are expressed at high levels in seawater and hypersaline gill and opercular epithelia and form defined sodium-selective pores in the paracellular pathway between ionocytes and accessory cells. This is a highly regulated paracellular pathway for sodium secretion necessary for survival of teleost fish and other vertebrates coping with saline environments. **Impact:** This research applies directly to understanding the function of salt secreting epithelia from fish gill and avian salt gland to salivary gland and mammary gland. We initiated an international collaborative team to attack this problem and have one paper published and a second in preparation: Marshall, W.S., Breves, J.P., **Doohan, E.M.**, Tipsmark, C.K., Kelly, S.P., Robertson, G.N. and Schulte, P.M. (2018) *claudin-10* isoform expression and cation selectivity change with salinity in salt-secreting epithelia of *F. heteroclitus* J. Exp. Biol. **221**: 1: DOI 10.1242/jeb168906.; Chen, Chun C., Marshall, William S., Robertson, George N., Cozzi, R.F.F. and Kelly, Scott P. Claudin-10 paralogs respond to salinity



challenge and localize to ionocytes of opercular skin and gill epithelia of *Fundulus heteroclitus*. (submitted to J exp Biol May 2019)

**B.** We recently discovered the voltage limitation of the Na<sup>+</sup> secretion mechanisms via regulated paracellular junctions, applicable to all vertebrate salt secreting epithelia. Cozzi, RRF, Robertson, G.N., \*Spieker, M., \*Claus, L.N., \*Zaparilla, G.M.M., \*Garrow, K.L. and Marshall, W.S. 2015. Paracellular pathway remodeling enhances sodium secretion by teleost fish in hypersaline environments. *J. Exp. Biol.* 218:1259-1269 2015 {4 citations}. The question was whether hypersalinity evoked alteration in the mechanism of salt secretion (i.e. active transcellular Cl<sup>-</sup> transport linked to passive paracellular Na<sup>+</sup>). We discovered that the elaboration of the paracellular pathway structurally and functionally increases the conductance of that pathway such that the diminished electrical gradient can still effectively secrete Na<sup>+</sup> via cation-conductive paracellular channels even into 2x seawater and higher salinities. Above 2x seawater, however, the animal is obliged to increase plasma Na<sup>+</sup> to maintain the critical voltage for secretion. **Impact:** This experimental model (opercular epithelium in hypersaline conditions) is ideal to reveal the junctional proteins that make up cation-selective junctions between ionocytes and accessory cells (the “Holy Grail” of claudin research).

**C.** Discovery of acclimation processes that allow fish to regulate ion transport in cold over-winter conditions. [\*Buhariwalla, H.E.C., \*Osmond, E.M., \*Barnes, K.R., Cozzi, R.R.F., Robertson, G.N. and Marshall, W.S. 2012. Control of ion transport by mitochondrion-rich chloride cells of eurythermic teleost fish: Cold shock vs. cold acclimation. *Comp. Biochem. Physiol.* 162A:234-244. {12 citations}; \*Barnes, K.R., Cozzi, R.R.F., Robertson, G.N. and Marshall, W.S. 2013 Cold acclimation of NaCl secretion in a eurythermic teleost: Mitochondrial function and gill remodeling. *Comp. Biochem. Physiol.* 168A:50-62 ({12 citations}); \*Malone, A., Cozzi, R.R.F. and Marshall W.S. 2014. Cold acclimation allows regulation of chloride secretion in a eurythermic teleost fish *Fundulus heteroclitus*. *Comp Biochem Physiol.* 180A:68-74] {3 citations} We discovered that, whereas cold shocked fish cannot regulate their ion transport, cold acclimated fish do regulate ion transport and selectively switch away from receptor-mediated neural control to direct cellular osmosensitive control of ion transport. There is clear regulation of membrane phospholipid composition with increased unsaturation in the cold, selectively using delta-9-desaturase. **Impact:** an innovation was the indirect detection of lipid phase changes using Arrhenius plots of *I<sub>sc</sub>*; briefly: the mitochondrial membrane melting temperature (*T<sub>m</sub>*) is 8 °C. Mummichogs are eurythermic and apparently acclimate to the cold simply by evoking one enzyme delta-9-desaturase and simply increasing monounsaturated fatty acids in cell membranes. The worldwide research group in cold physiology is small, but these papers are well cited nevertheless.

**D.** Discovery of Focal Adhesion Kinase involvement in osmotic regulation of NaCl secretion by seawater ionocytes; 4 papers. [Marshall, W.S., \*Watters, K.D., \*Hovdestad, L.R., Cozzi, R.R.F.,

\*Katoh, F. CFTR Cl<sup>-</sup> channel functional regulation by phosphorylation of focal adhesion kinase at tyrosine 407 in osmosensitive ion transporting mitochondria rich cells of euryhaline killifish. *J. exp. Biol.* 212:2365-2377 (2009) {27 citations}. Marshall, W.S., C.G. Ossum and E.K. Hoffmann. Hypotonic shock mediation by p38 MAPK, JNK, PKC, FAK, OSR1 and SPAK in osmosensing chloride secreting cells of killifish opercular epithelium. *J. exp. Biol.* 208:1063-1077 (2005). {83 citations}, Hoffmann, E.K., T. Schettino and W.S. Marshall. The role of volume-sensitive ion transport systems in regulation of epithelial transport. *Comp. Biochem. Physiol.* 148A:29-43 (2007) {52 citations}, Marshall, W.S., \*Katoh, F., \*Main, H.P., \*Sers, N. and Cozzi, R.R.F. Focal adhesion kinase and  $\beta$ 1 integrin regulation of Na<sup>+</sup>,K<sup>+</sup>,2Cl<sup>-</sup> cotransporter in osmosensing ion transporting cells of killifish *Fundulus heteroclitus*. *Comp. Biochem. Physiol.* 150A:288-300 (2008) {21 citations}], Uniquely, teleost fish use FAK phosphorylated at Y407 in osmosensitive ion transport and cell volume regulation. In collaboration with James Chair Prof. E.K. Hoffmann (U Copenhagen), we showed that the osmosensitive pathways terminate at NKCC in the basolateral and at CFTR in the apical membrane of seawater ionocytes. **Impact:** These papers with fish CFTR led to human airway cellular research into the hitherto unknown *tyrosine phosphorylation and activation pathway of human CFTR* at Johns Hopkins U. School of Medicine (Liang et al. 2011) and McGill U. (Billet et al. 2013, 2015). Osmosensitivity and volume regulation in epithelia has become a hot research area.

**E.** Identification of CFTR as the hormone-regulated anion channel of salt secretion in teleost fishes, 6 papers: [Marshall, W.S., E.M. \*Lynch and R.F. Cozzi. Redistribution of immunofluorescence of CFTR anion channel and NKCC cotransporter in chloride cells during adaptation of the killifish *Fundulus heteroclitus* to sea water. *J. exp. Biol.* 205: 1265-1273 (2002). {101 citations}, Marshall, W.S., S.E. Bryson, A. Midelfart and W.F. \*Hamilton. Low conductance anion channel activated by cAMP in teleost Cl<sup>-</sup> secreting cells. *Am. J. Physiol.* 268:R963-R969 (1995) {53 citations}, Singer, T.D., S.J. Tucker, W.S. Marshall and C.F. Higgins. A divergent CFTR homologue: Highly regulated salt transport in the euryhaline teleost *Fundulus heteroclitus*. *Am. J. Physiol.* 274:C715-C723 (1998) {114 citations}, Marshall, W.S., S.E. Bryson and D. \*Garg. Alpha-2 adrenergic inhibition of chloride transport by opercular epithelium is mediated by intracellular Ca<sup>2+</sup>. *Proc. Nat. Acad. Sci. U.S.A.* 90:5504-5508 (1993) {35 citations}, Marshall, W.S., T.R. \*Emberley, S.E. Bryson and S.D. McCormick. Time course of salinity adaptation in a strongly euryhaline estuarine teleost *Fundulus heteroclitus*: A multivariable approach. *J. exp. Biol.* 202:1535-1544 (1999). {137 citations}, W.S. Marshall and T.D. Singer. Cystic Fibrosis Transmembrane Conductance Regulator in teleost fish. *Biochim. Biophys Acta*, Reviews in Biomembranes 1566: 16-27, (2002). {55 citations}]. Using patch clamp electrophysiology and early cloning techniques, our lab, in collaborations with U of T Hosp for Sick Children (T Singer, JR Riordan) and University of Oxford (CF Higgins, SJ Tucker), discovered teleost fish CFTR, the electrophysiological characteristics of the ion channel, and pivotal regulatory aspects (PKA/ATP activation; upregulation of gene and protein and trafficking of protein during seawater acclimation).

**Impact:** this research is now classic (495 citations in total) and it helped to establish the marine vertebrate salt secretion paradigm, which appears in many biology/physiology textbooks. These works still are heavily cited after 15-26 years.

F. Discovery of gonadotropin-regulated potassium secretion and sodium absorption in teleost fish sperm duct. [Marshall, W.S., S.E. Bryson and D.R. Idler Gonadotropin action on sperm duct epithelium: Ion transport stimulation mediated by cAMP and  $\text{Ca}^{2+}$ . *Gen. Comp. Endocrinol.* 90:232-242 (1993). {10 citations}, Marshall, W.S., S.E. Bryson, and D.R. Idler. Gonadotropin stimulation of  $\text{K}^+$  secretion and  $\text{Na}^+$  absorption by brook trout (*Salvelinus fontinalis*) sperm duct epithelium. *Gen. Comp. Endocrinol.* 75: 118-128 (1989). {39 citations}, Marshall, W.S. and S.E. Bryson. Evidence for  $\text{Cl}^-$ -dependent  $\text{K}^+$  secretion by the blood-testis barrier of brook trout. *Can. J. Zool.* 66:1603-1609 (1988). {10 citations}] Direct actions of vertebrate gonadotropins are very few and this one, mediated by cAMP, rapidly turns on  $\text{K}^+$  active secretion to increase milt  $\text{K}^+$  levels to 5-10 fold above plasma concentrations, which in turn keeps sperm depolarized and inactivated until spawning. At spawning, it is the rapid decrease in  $\text{K}^+$  that hyperpolarizes the sperm in seawater or freshwater and activates sperm motility. In process of this discovery, we also showed that although teleost fishes have LH- and FSH-like gonadotropins, there is only one class of GTH receptor. **Impact:** Gonadotropin functions are recognized in textbooks on comparative endocrinology.

## LIST OF RESEARCH CONTRIBUTIONS

### FULL PAPERS IN REFEREED JOURNALS

1. Marshall, W.S.: Effects of hypophysectomy and ovine prolactin on the epithelial mucus-secreting cells of the pacific staghorn sculpin, *Leptocottus armatus* (teleostei: cottidae). *Can. J. Zool.* 54:1604-1609 (1976). {24 citations}
2. Marshall, W.S.: Transepithelial potential and short-circuit current across the isolated skin of *Gillichthys mirabilis* (teleostei: gobiidae), acclimated to 5% and 100% sea water. *J. Comp. Physiol.* 114:157-165 (1977). {70 citations}[85 citations]
3. Marshall, W.S.: On the involvement of mucus secretion in teleost osmoregulation. *Can. J. Zool.* 56:1088-1091 (1978). {51 citations}
4. Marshall, W.S. Effects of salinity acclimation, ovine prolactin, and cortisol on the mucus cells of *Leptocottus armatus* (teleostei:cottidae). *Gen. Comp. Endocrinol.* 37:358-368 (1979). {20 citations}
5. Marshall, W.S. and Bern, H.A. Teleostean urophysis: urotensin II and ion transport across the isolated skin of a marine teleost. *Science* 204:519-521 (1979). {57 citations}
6. Marshall, W.S. and Nishioka, R.S. Relation of mitochondria-rich chloride cells to

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  8. Bern, H.A., C.A. Bisbee, N.L. Collie, J.K. Foskett, B. Hughes, C.A. Loretz and W.S. Marshall. Failure of ovine prolactin to elicit rapid effects on osmoregulatory surfaces. *Gen. Comp. Endocrinol.* 44:128-130 (1981). {9 citations}
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  10. Marshall, W.S. Sodium dependency of active chloride transport across isolated fish skin (*Gillichthys mirabilis*). *J. Physiol. Lond.* 319:165-178 (1981). {21 citations}
  11. Marshall, W.S. Active transport of  $Rb^+$  across the skin of the teleost *Gillichthys mirabilis*. *Am. J. Physiol.* 241:F482-F486 (1981). {9 citations}
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  13. Klyce, S.D., K.A. Palkama, A.H. Neufeld, M. Harkonen, W.S. Marshall, S. Hutaniitty, and K.P. Mann. Neural serotonin stimulates chloride transport in the rabbit corneal epithelium. *Invest. Ophthalmol. Vis. Sci.* 23:181-192 (1982). {45 citations}
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  16. Lessman, C.A. and W.S. Marshall. Electrophysiology of insulin- and progesterone-induced meiosis in *Rana pipiens* oocytes. *J. Exp. Zool.* 231:257-266, (1984). {14 citations}
  17. Marshall, W.S. and S.D. Klyce. Cellular mode of serotonin action in the rabbit corneal epithelium. *Biochim. Biophys. Acta.*, 778:139-143 (1984). {9 citations}
  18. Marshall, W.S. Paracellular ion transport in trout opercular epithelium models osmoregulatory effects of acid precipitation. *Can. J. Zool.* 63:1816-1822 (1985). {45 citations}
  19. Marshall, W.S., H.R. \*Habibi and C.A. Lessman. Electrophysiology of oocytes during meiotic maturation and after ovulation in brook trout (*Salvelinus fontinalis*). *Can. J. Zool.* 63:1904-1908 (1985). {2 citations}
  20. Marshall, W.S. Independent  $Na^+$  and  $Cl^-$  active transport by urinary bladder epithelium of brook trout. *Am. J. Physiol.* 250:R227-R234 (1986). {18 citations}
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- epithelium. *Can. J. Zool.* 66:912-918 (1988). {68 citations}
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  26. Marshall, W.S., S.E. Bryson and **M.M. Sapp**. Volume regulation in glutathione-treated brook trout (*Salvelinus fontinalis*) erythrocytes. *Fish Physiol. Biochem.* 8:19-28 (1990). {9 citations}
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  30. Marshall, W.S., S.E. Bryson and **D. Garg**.  $\alpha_2$ -adrenergic inhibition of chloride transport by opercular epithelium is mediated by intracellular Ca<sup>2+</sup>. *Proc. Nat. Acad. Sci. U.S.A.* 90:5504-5508 (1993). {39 citations}
  31. Marshall, W.S., S.E. Bryson and D.R. Idler. Gonadotropin action on sperm duct epithelium: Ion transport stimulation mediated by cAMP and Ca<sup>2+</sup>. *Gen. Comp. Endocrinol.* 90:232-242 (1993). {6 citations}
  32. Wood, C.M. and W.S. Marshall. Ion balance, acid-base regulation, and chloride cell function in the common killifish *Fundulus heteroclitus* - a freely euryhaline estuarine teleost. *Estuaries* 17:34-52 (1994). {141 citations}
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  34. Marshall, W.S., S.E. Bryson, **J.S. Burghardt** and P.M. Verbost. Ca<sup>2+</sup> transport by opercular epithelium of the freshwater adapted euryhaline teleost *Fundulus heteroclitus*. *J. Comp. Physiol. B.* 165:268-277 (1995). {32 citations}
  35. Patrick, M.L., Pärt, P., Marshall, W.S. and C.M. Wood. Characterization of ion and acid-base transport in fresh water adapted mummichog (*Fundulus heteroclitus*). *J. Exp. Zool.* 279:208-219 (1997). {67 citations}
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  46. Marshall, W.S., **J.A. Howard**, R.R.F. Cozzi, and **E.M. Lynch** NaCl and fluid secretion by the intestine of the teleost *Fundulus heteroclitus*: Involvement of CFTR. *J. exp. Biol.* **205**:745-758 (2002) {64 citations}
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  56. **Barnes, K.R.**, Cozzi, R.R.F., Robertson, G.N. and Marshall, W.S. 2013 Cold acclimation of  $\text{NaCl}$  secretion in a eurythermic teleost: Mitochondrial function and gill remodeling. *Comp. Biochem. Physiol. A Molec. Integ. Physiol.* 168:50-62 {12 citations}
  57. **Malone, A.**, Cozzi, R.R.F. and Marshall W.S.. 2014. Cold acclimation allows regulation of chloride secretion in a eurythermic teleost fish *Fundulus heteroclitus*. *Comp Biochem Physiol. Part A Molec. Integ. Physiol.* 180:68-74 {3 citation}
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  60. **Lucie Gerber**, Frank B. Jensen, Steffen S. Madsen and William S. Marshall. 2016. Nitric oxide inhibition of salt secretion in the opercular epithelium of seawater-acclimated killifish, *Fundulus heteroclitus*. *J. Exp. Biol.* 219: 3455-3464 {4 citations}
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  63. Marshall, W.S., Breves, J.P., **Doohan, E.M.**, Tipsmark, C.K., Kelly, S.P., Robertson, G.N. and Schulte, P.M. (2018) *claudin-10* isoform expression and cation selectivity change with salinity in salt-secreting epithelia of *F. heteroclitus*

## BOOK CHAPTERS AND REVIEWS CONTAINING NEW DATA

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