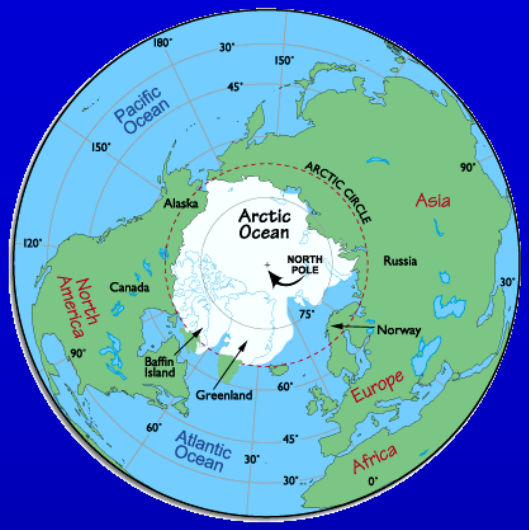


Brucellosis in the Arctic

Department of Food Safety and Infection Biology
Section of Arctic Veterinary Medicine

Jacques Godfroid

Brucellosis (*Brucella ceti* and *Brucella pinnipedialis*) in marine mammals

Brucellosis (*Brucella suis* biovar 4) in reindeer

Jacques Godfroid

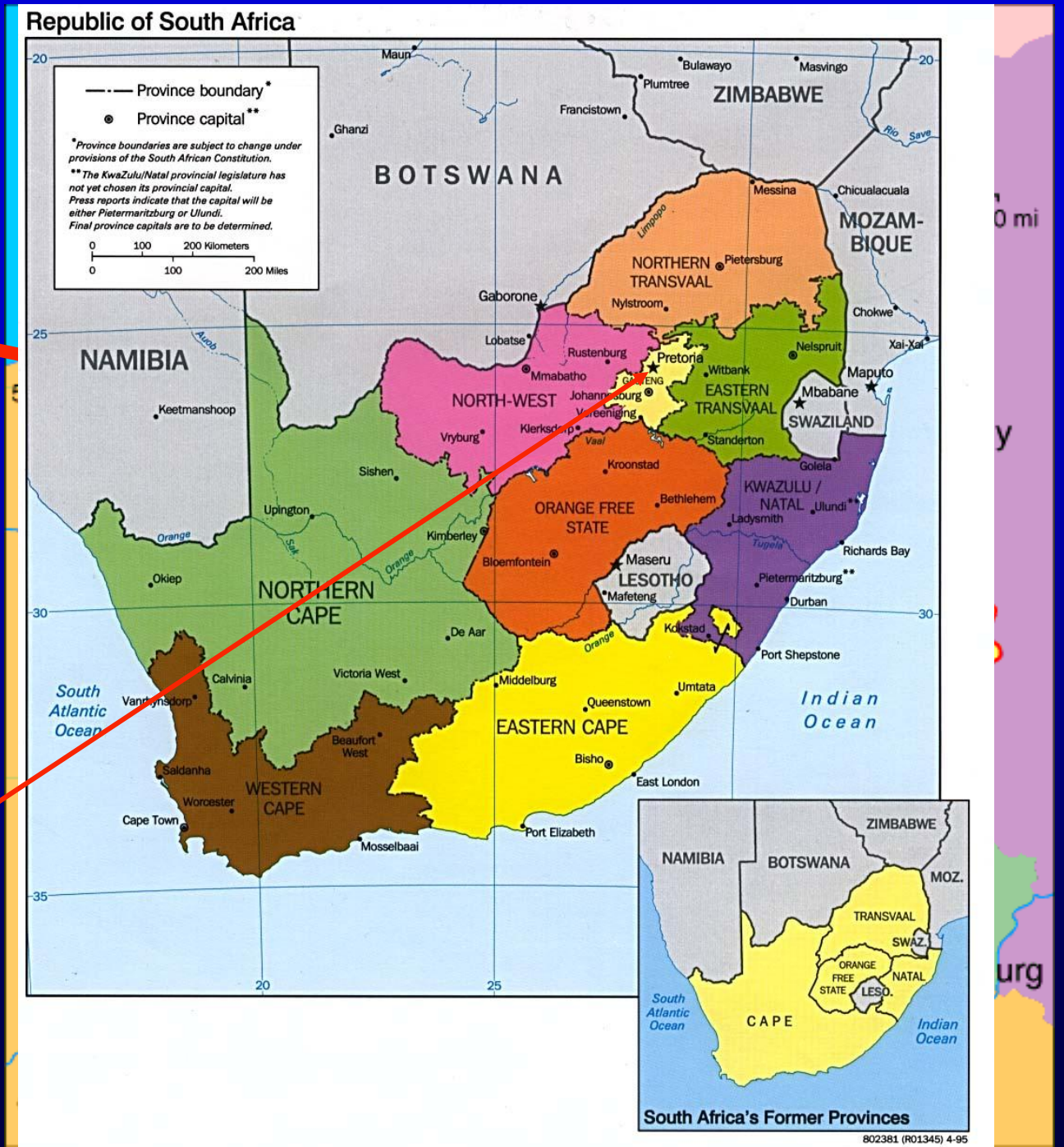
DVM

Msc

PhD

2004-2007

UP-OP-DVTD



Norges veterinærhøgskole

Norwegian School of Veterinary Science

Since January 2008

Seksjon for arktisk veterinærmedisin

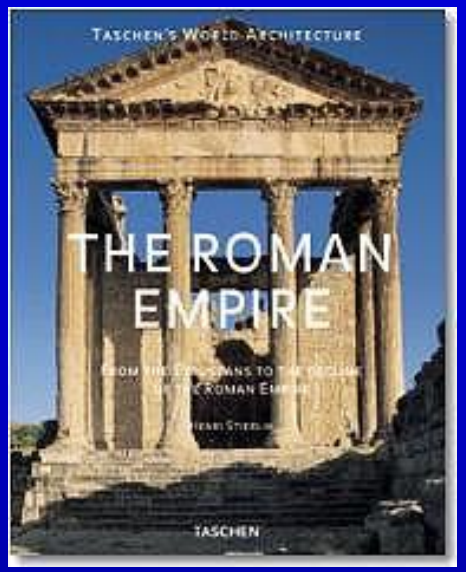
Section of Arctic Veterinary Medicine

“There is nothing permanent but change”

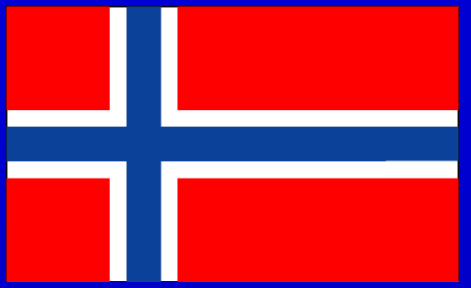
Anonym

« We regard brucellosis as the world’s most widespread of all zoonoses and apart from its toll on people, it has an enormous impact on the animal industry »

WHO, 1998


TASCHEN'S WORLD ARCHITECTURE
THE ROMAN EMPIRE
TASCHEN


OCÉANUS
GÁLLIA
GERMÁNIA
GÁLLIA NARBONÉNSIS 121
GÁLLIA CISALPÍNA 222/191
ILLÝRICUM 167
PONTUS EUXÍNUS
HISPÁNIA CITÉRIOR 197
HISPÁNIA ULTÉRIOR 197
CÒRSICA ET SARDÍNIA 227
Roma
ITÁLIA
MARE TYRRHÉNUM
MARE ADRIÁTICUM
MARE IÓNIUM
MACEDÓNIA 146
THRÁCIA
BITHYNIA-PONTUS 74
GALÁTIA
ARMENIA
ÁSIA 129
CILÍCIA 64
SYRIA 64
PARTHI
ACHÁIA 146
MARE
NUMÍDIA
ÁFRICA 146
SICÍLIA 241
INTÉRNUM
MAURITÁNIA
CYRENAÏCA 74
LÍBYA
AEGÝPTUS
Extension sous l'Empire
LE MONDE ROMAIN AU MILIEU DU Ier S. AV. J.-C.



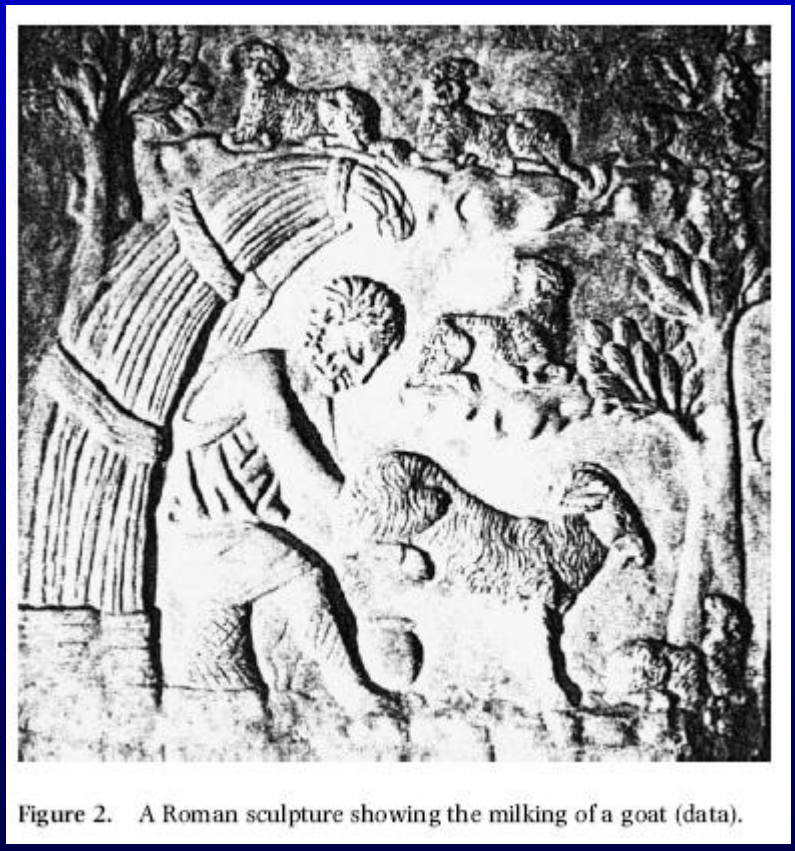


Figure 2. A Roman sculpture showing the milking of a goat (data).

What happened in Pompeii
and
Herculaneum

August 24, 79 before Christ ?

Bacteria in Two-millennia-old Cheese, and Related Epizoonoses in Roman Populations

L. Capasso

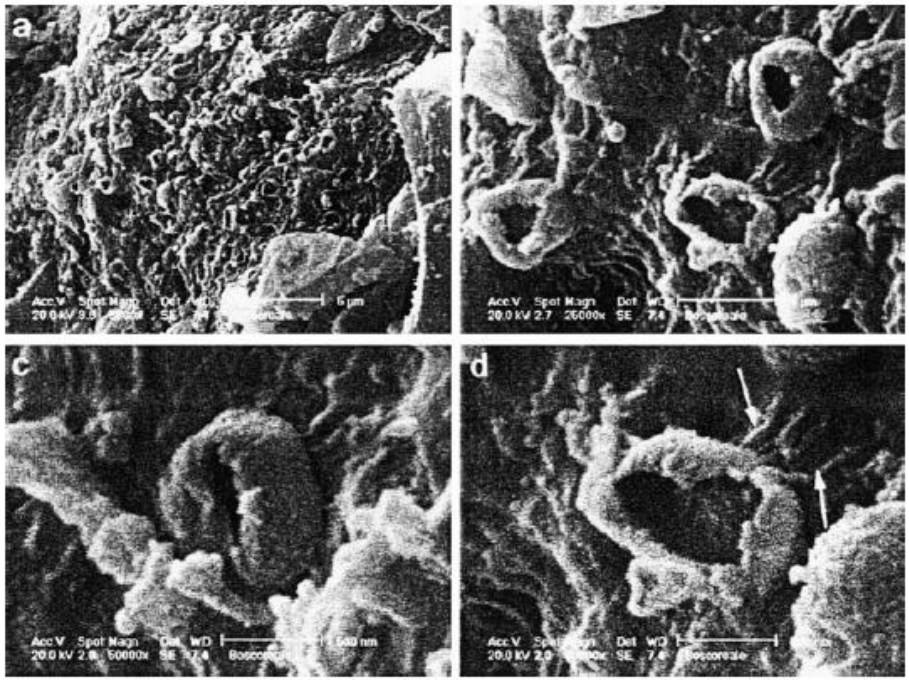
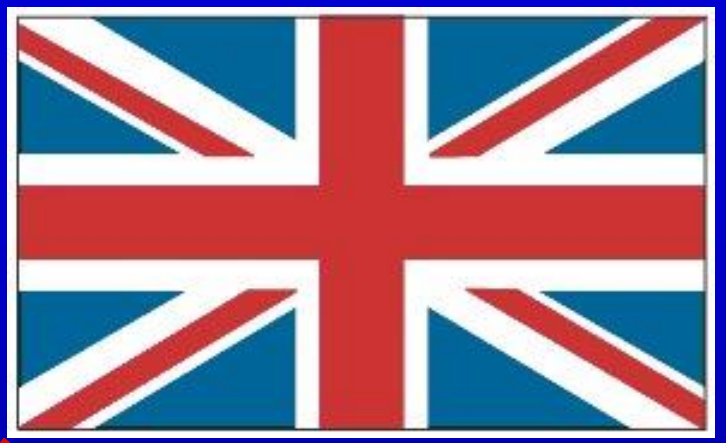
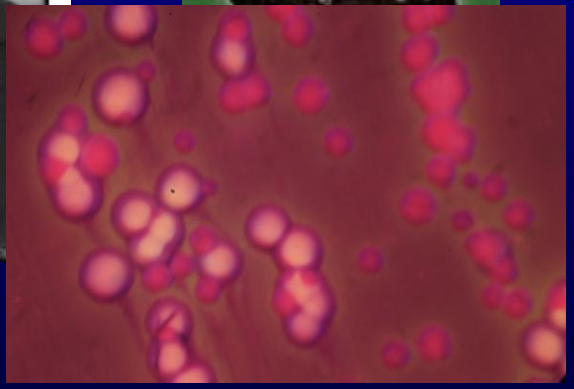
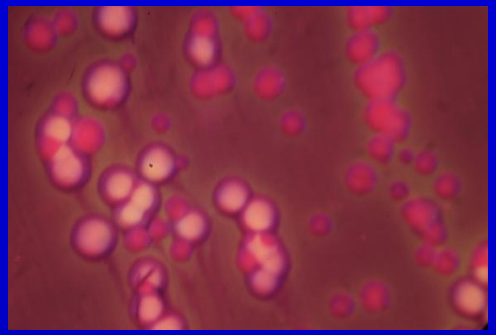


Figure 5. Cocci-like bacterial particles in a high-density colony (a: 5000×) in the Herculaneum carbonized cheese (79 AD); The monomorphic and monodimensional cocci (around 0.8 μ) show large holes with invaginated borders (b: 25,000×). In some case we can estimate the thickness of bacterial-wall (about 10 mμ) (c: 50 000×), and we can demonstrate the presence of proteinic bridges between the bacterial walls and the cheese mixture (arrows in d: 50,000×). These remain of bacterial walls are morphologically comparable with *Streptococci* or *Brucellae*.



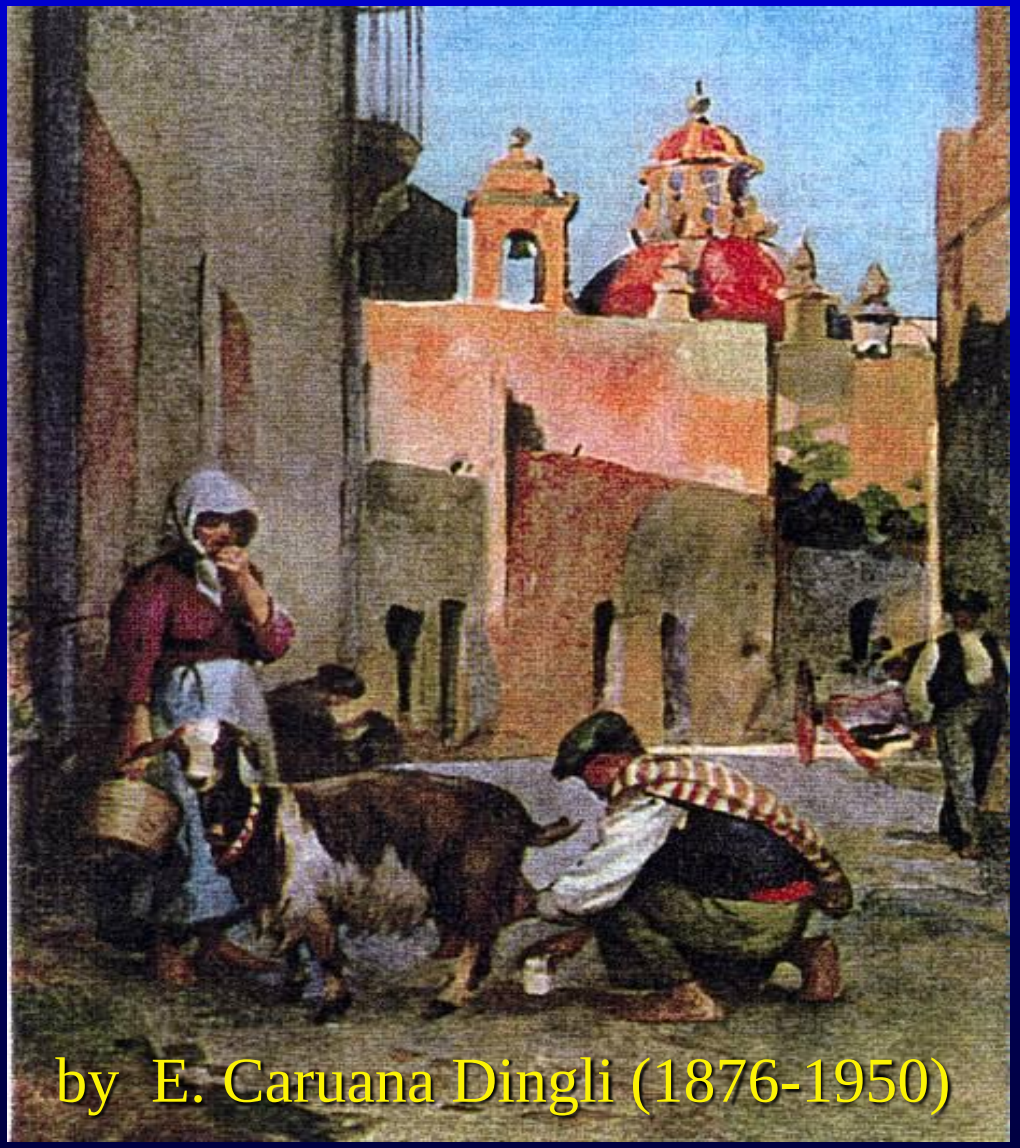
Sir David Bruce





Brucellosis

The Maltese goat



by E. Caruana Dingli (1876-1950)

Sir Temi Zammit

Brucella species and biovars, preferential hosts and pathogenicity for humans, before 1994

Species	Biovars	Preferential host(s)	Pathogenicity in humans
B. melitensis	1-3	Sheep, Goat	High
B. abortus	1-6, 9	Cattle	High
B.suis	1, 3	Pig	High
	2	Wild boar, Hare	No
	4	Reindeer, Caribou	High
	5	Rodents	?
B. neotomae	-	Desert rat	Moderate
B. ovis	-	Ram	No
B. canis	-	Dog	Moderate

Identification of an unknown wildlife reservoir of *Brucella suis* biovar 2 in Western Europe

Godfroid J., Michel P., Uytterhaegen L., De Smet K., Rasseneur F., Boelaert F., Saegerman C., Patigny X., 1994. Brucellose enzootique (*Brucella suis* biotype 2) chez le sanglier (*Sus scrofa*) en Belgique. Ann. Med. Vet., 138: 263-268.

Brucella species and biovars, preferential hosts and pathogenicity for humans in 2010

Species	Biovars	Preferential host(s)	Pathogenicity in humans
B. melitensis	1-3	Sheep, Goat	High
B. abortus	1-6, 9	Cattle	High
B. suis	1, 3	Pig	High
	2	Wild boar, Hare	No
	4	Reindeer, Caribou	High
	5	Rodents	?
B. neotomae	-	Desert rat	Moderate
B. ovis	-	Ram	No
B. canis	-	Dog	Moderate
B. pinnipedialis	-	Cetaceans	?
B. ceti	-	Seals	?
B. microti	-	Soil, Vole, Fox	?
B. inopinata	-	Human	?

?: Although human cases have been described, the actual pathogenicity remains unknown

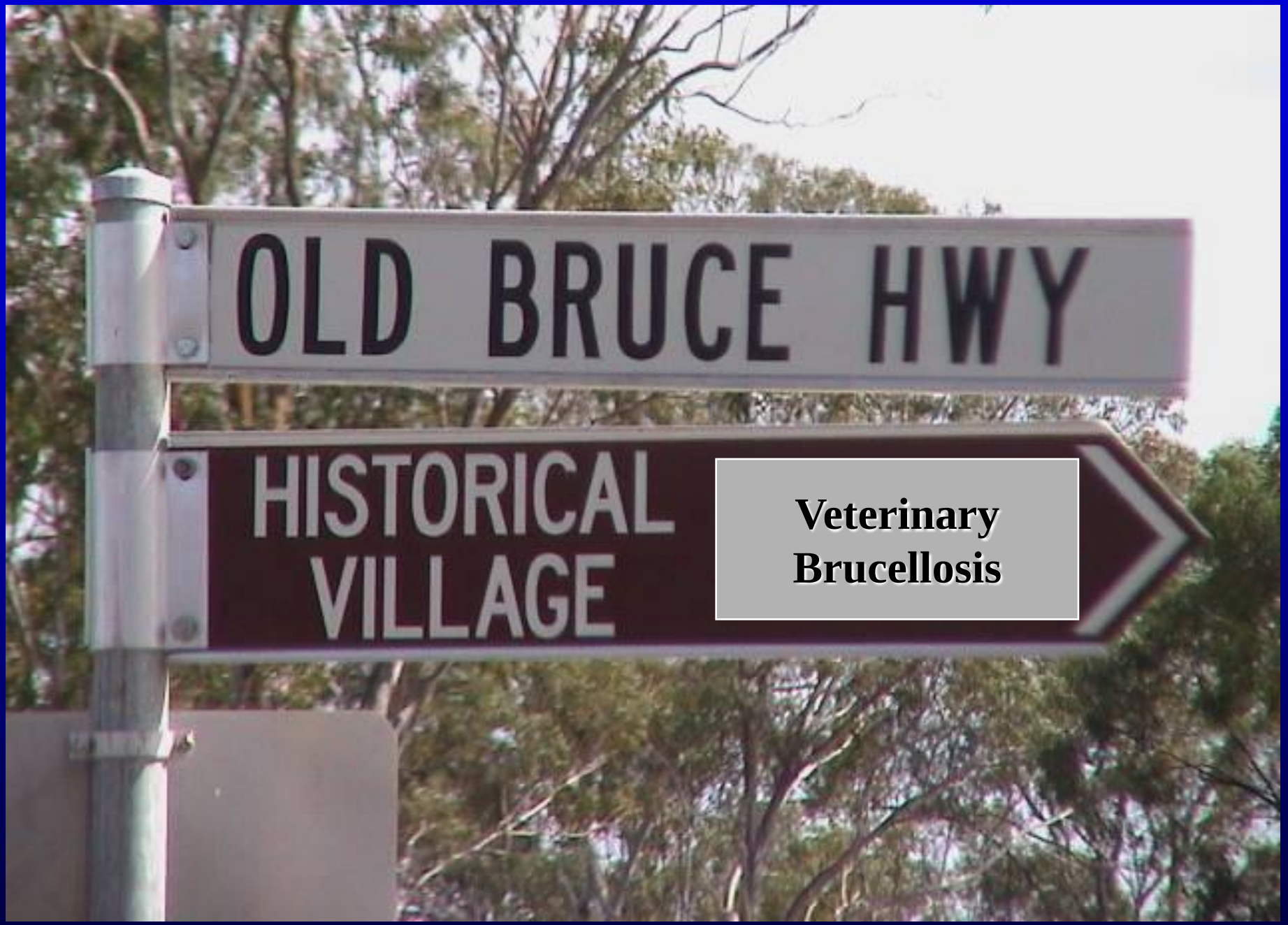
Marine Mammal Brucellosis ... ?

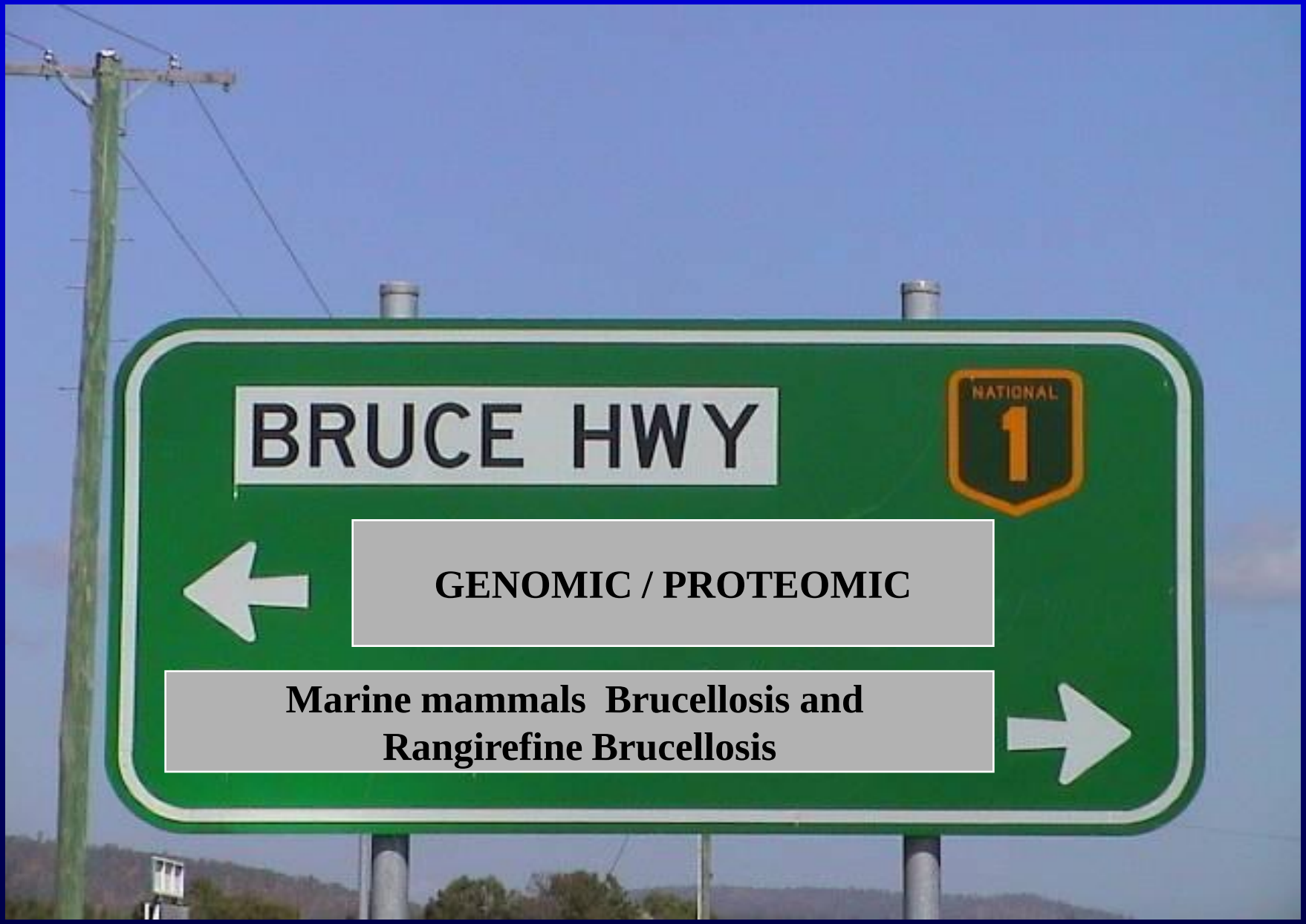
- In 1994, the first description of a *Brucella* species isolated from an aborted fetus of a captive bottlenose dolphin (*Tursiops truncatus*) in San Diego, California was reported by Ewalt *et al.*

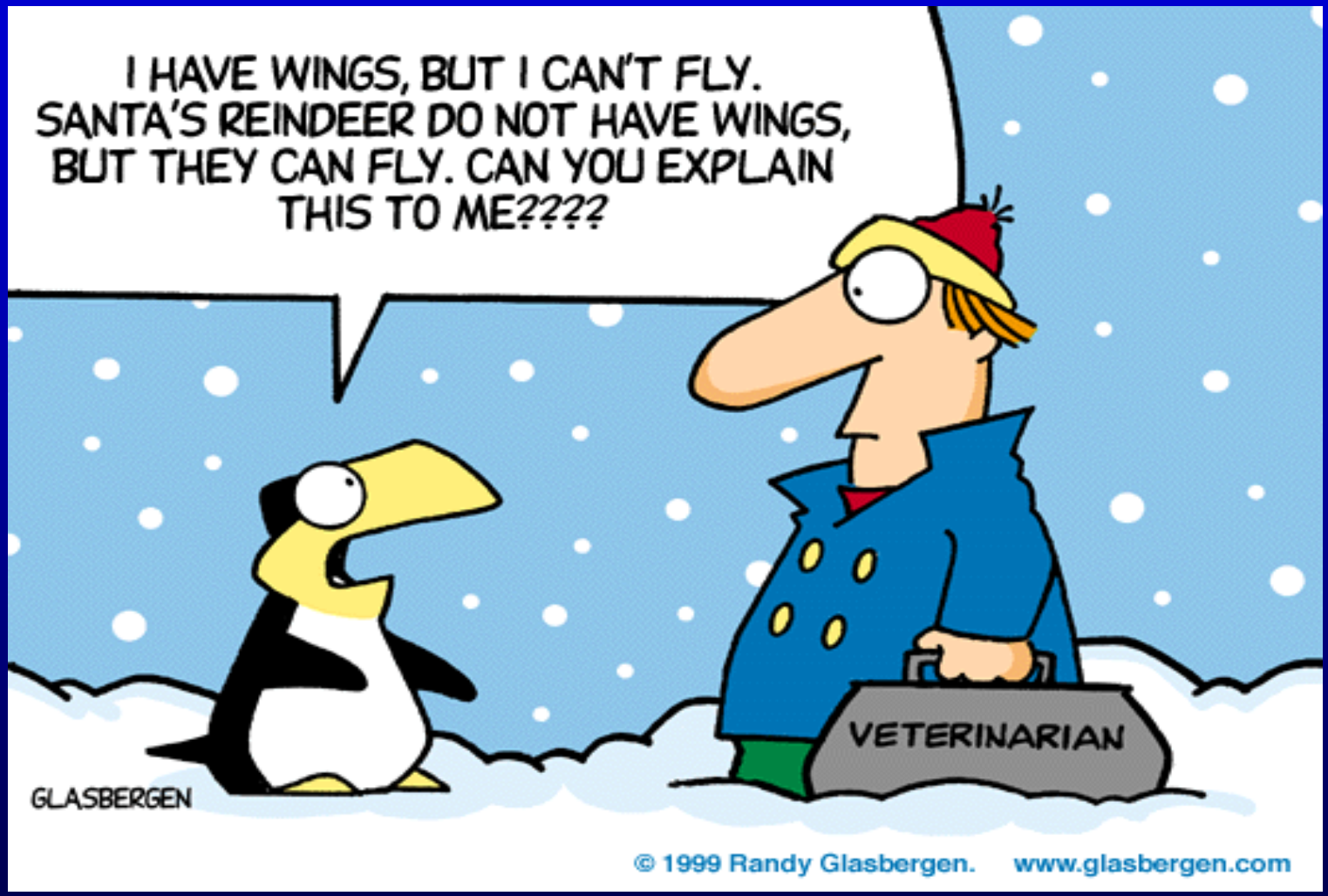
- In 1996, the first presumptive (serological) evidence of *Brucella* spp. exposure in Atlantic walruses (*Odobenus rosmarus rosmarus*) and ringed seals (*Phoca hispida*) of Arctic Canada was reported by Nielsen *et al.*

- In 1996, Foster *et al.*, and and Ross *et al.*, reported the isolation of *Brucella* species in North Sea seal and cetacean (dolphins and porpoises) populations in stranded or by-caught animals, around the Scottish coast

- Questions:
  - New *Brucella* species ... ?
  - Presence of *Brucella* in a wide range of marine mammals ?
  - Significance of the presence of *Brucella* in marine mammals ?
  - Zoonotic potential ?


OLD BRUCE HWY
HISTORICAL VILLAGE
Veterinary Brucellosis


BRUCE HWY
NATIONAL
1
GENOMIC / PROTEOMIC
Marine mammals Brucellosis and
Rangirefine Brucellosis


I HAVE WINGS, BUT I CAN'T FLY. SANTA'S REINDEER DO NOT HAVE WINGS, BUT THEY CAN FLY. CAN YOU EXPLAIN THIS TO ME????
VETERINARIAN
GLASBERGEN
© 1999 Randy Glasbergen. www.glasbergen.com


Link ?

Brucellose enzootique (*Brucella suis* biotype 2) chez le sanglier (*Sus scrofa*) en Belgique. Ann. Med. Vet., 138: 263-268. Godfroid J., Michel P., Uytterhaegen L., De Smet K., Rasseneur F., Boelaert F., Saegerman C., Patigny X., 1994.


Biovars 1 & 3
Biovar 2


Brucella suis
Biovar 4

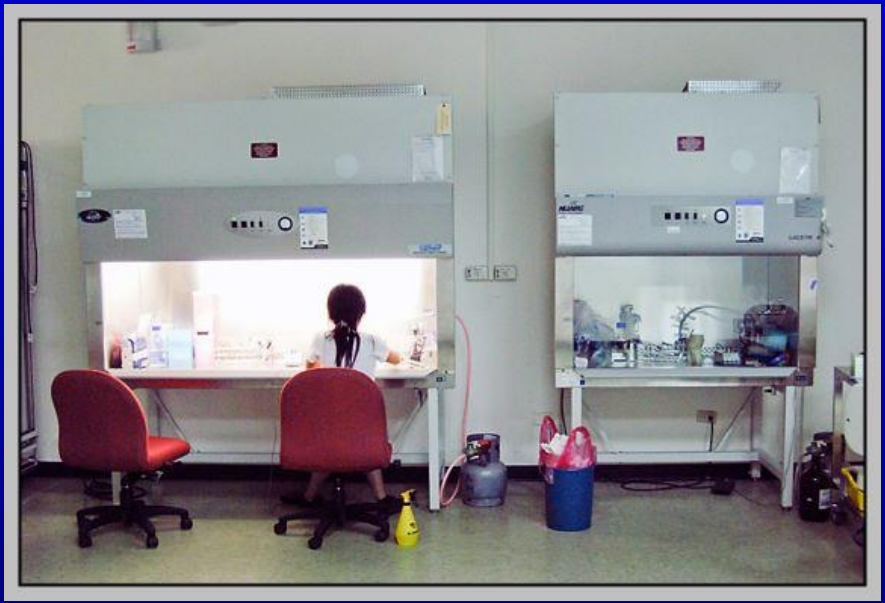

!


EUROPE
15° W
0°
15° E
30° E
45° E
60° E
Barents Sea
ARCTIC CIRCLE
Norwegian S
Iceland
Faroe Is (Denm
60° N
Atlantic Ocean
Ireland
UI
50° N
Luxembourg
Bay of Biscay
Andor
40° N
Spain
Portugal
Gibraltar (UK)
Morocco
30° N
©GraphicMaps.com
©GraphicMaps.com

1994

Field work

Now Laboratory work!



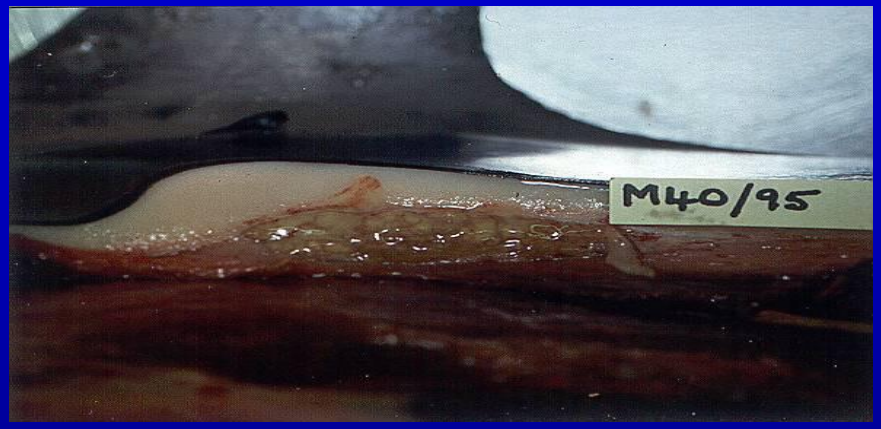
First, serology !

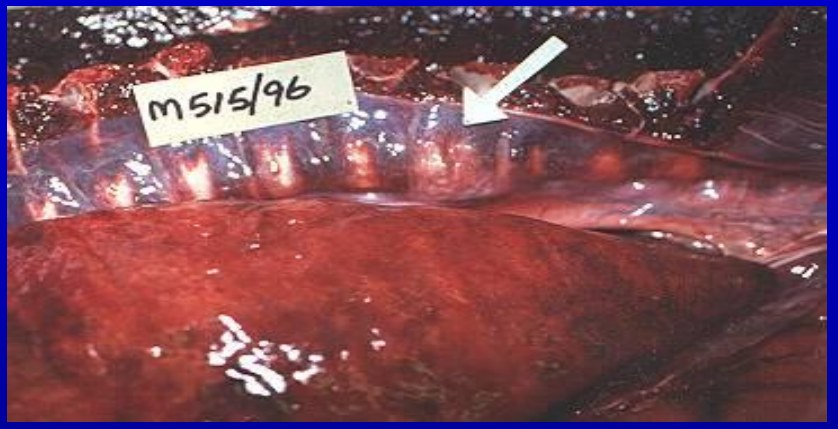
Evidence of *Brucella* infection in marine mammals in the North Atlantic Ocean

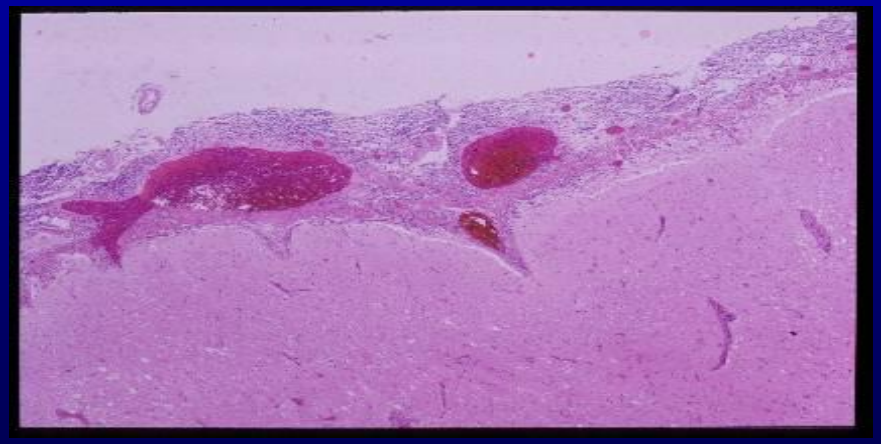
Tryland M, Kleivane L, Alfredsson A, Kjeld M, Arnason A, Stuen S, Godfroid J. 1999. Vet. Rec., 144: 588-592.

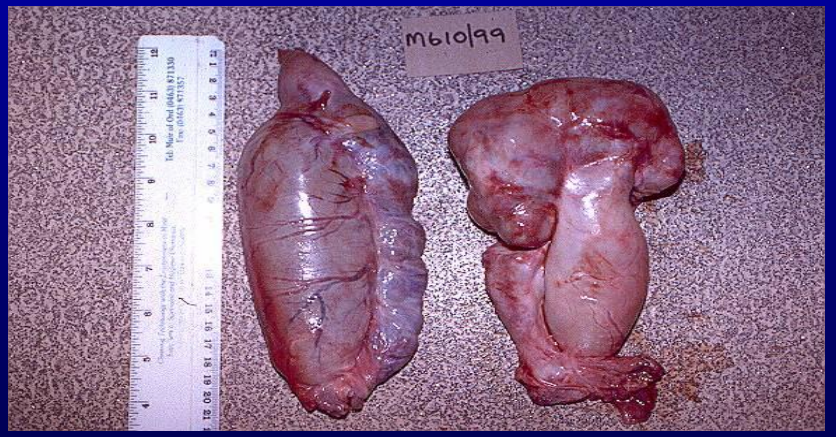
- **1370 Serum samples, from different sea mammals species caught during the 1983-1996 period**
- **Anti-*Brucella* antibodies were detected in all the species investigated, except for the bearded seal (*Erignathus barbatus*), with the following prevalences:**
  - ✓ **hooded seals (*Cystophora cristata*) 35 per cent**
  - ✓ **harp seals (*Phoca groenlandica*) 2 per cent**
  - ✓ **ringed seals (*Phoca hispida*) 10 per cent**
  - ✓ **minke whales (*Balaenoptera acutorostrata*) 8 per cent**
  - ✓ **Fin whales (*Balaenoptera physalus*) 11 per cent**
  - ✓ **Sei whales (*Balaenoptera borealis*) 14 per cent**

Then Pathology (photos: G. Foster & T. Patterson)









Gonzalez L., Patterson I. A., Reid R.. J., Foster G., Barberan M., Blasco J. .M., Kennedy S., Howie F. E., Godfroid J., MacMillan A. P., Schock A., Buxton D., 2002. Chronic Meningoencephalitis Associated with Brucella sp. Infection in Live-stranded Striped Dolphins (Stenella coeruleoalba). J. Comp. Pathol., 126: 147-52.

Then bacteriology !

- **An isolate belonging to the genus *Brucella* was obtained from the liver and spleen of one of the seropositive minke whale**

Clavareau C., Wellemans V., Walravens K., Tryland M., Verger J.-M., Cloeckaert A., Letesson J.-J., Godfroid J., 1998. Phenotypic and Molecular Characterization of a *Brucella* strain Isolated from a Minke Whale (*Balaenoptera acutorostrata*). Microbiology, 144: 3267-3273.

- **This suggests that antibodies against the surface lipopolysaccharide of *Brucella* species are widely distributed among marine mammals in the North Atlantic Ocean**

International Journal of Systematic and Evolutionary Microbiology (2007), **57**, 2688–2693 DOI 10.1099/ijs.0.65269-0

Brucella ceti sp. nov. and *Brucella pinnipedialis* sp. nov. for *Brucella* strains with cetaceans and seals as their preferred hosts

Geoffrey Foster,[1] Bjorn S. Osterman,[2] Jacques Godfroid,[3] Isabelle Jacques[4,5] and Axel Cloeckaert[4]

Correspondence
Geoffrey Foster
Geoffrey.Foster@sac.co.uk

[1]SAC Veterinary Services, Inverness IV2 4JZ, UK

[2]Department of Clinical Microbiology, Karolinska University Hospital, MTC, Stockholm SE-17176, Sweden

[3]Faculty of Veterinary Science, Department of Veterinary Tropical Diseases, University of Pretoria, Onderstepoort 0110, South Africa

[4]INRA, UR1282, Infectiologie Animale et Santé Publique, IASP, Nouzilly, F-37380, France

[5]Institut Universitaire de Technologie, Université François Rabelais, 29 rue du Pont-Volant, 37082 Tours cedex 2, France

Classification of *Brucella spp*. isolated from marine mammals by

MLVA

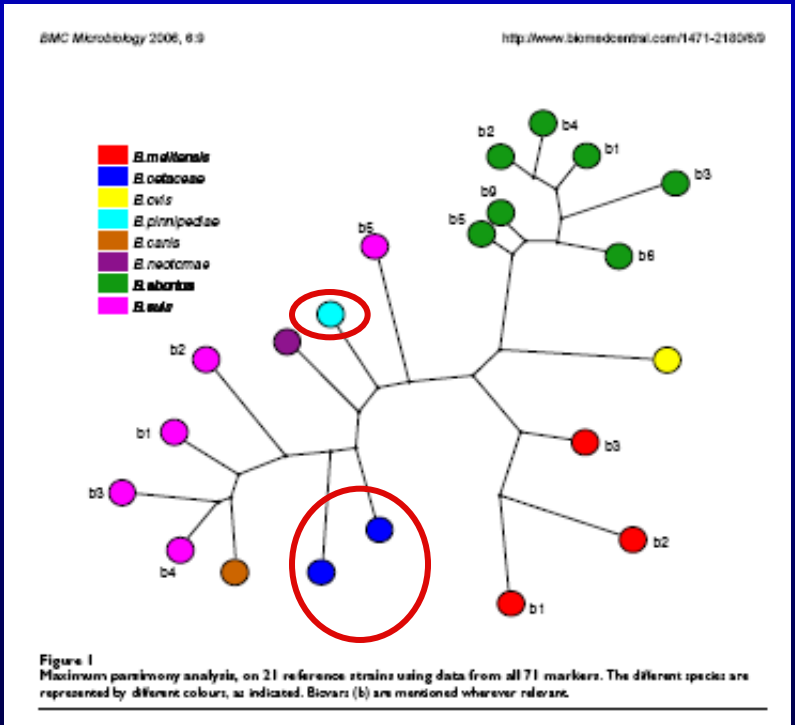


Figure 1
Maximum parsimony analysis, on 21 reference strains using data from all 71 markers. The different species are represented by different colours, as indicated. Biovars (b) are mentioned wherever relevant.

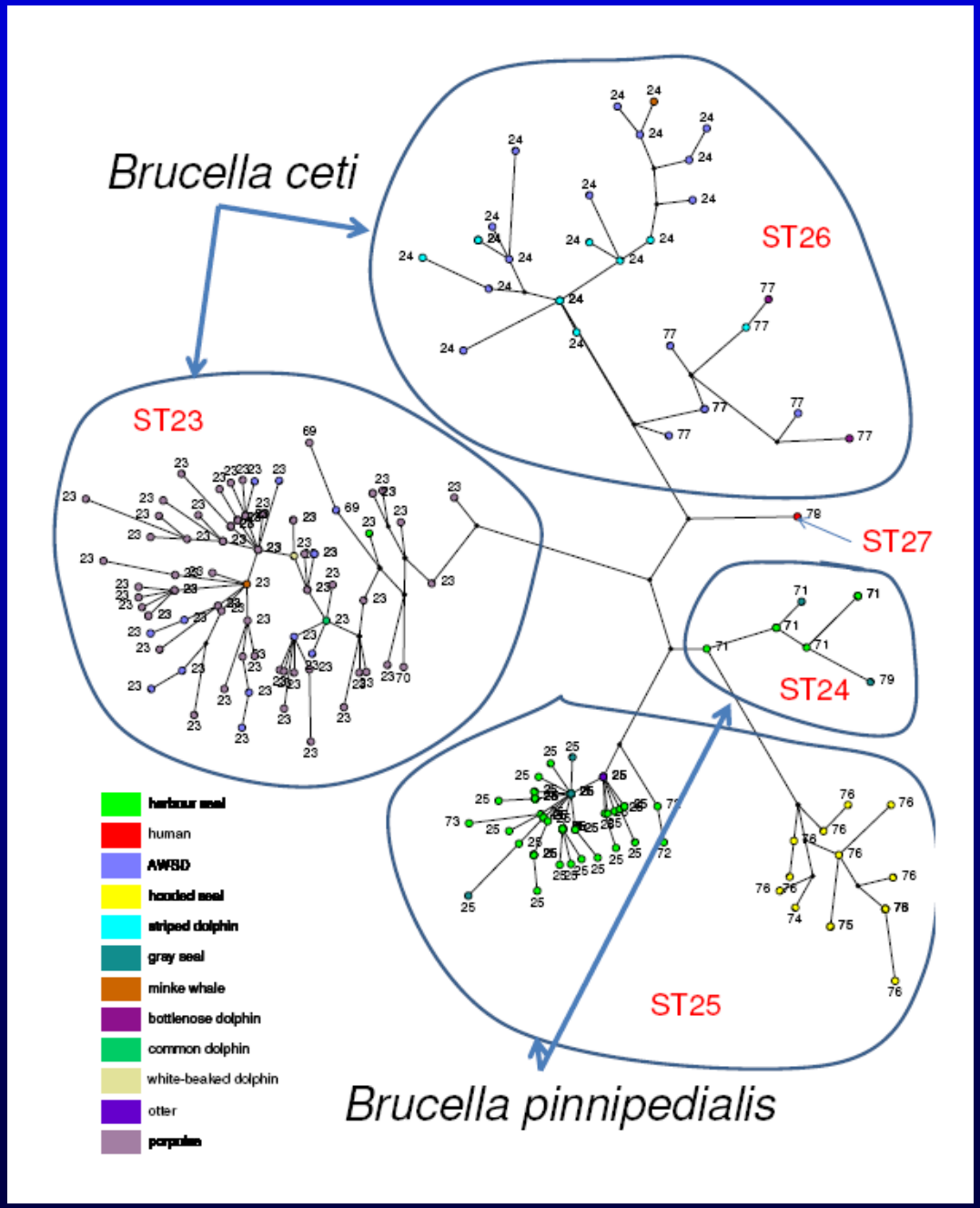
MARKER	Number of repeat
Bruce 04	6
Bruce 06	2
Bruce 07	6
Bruce 08	5
Bruce 09	3
Bruce 11	8
Bruce 12	7
Bruce 16	7
Bruce 18	4
Bruce 21	9
Bruce 30	6
Bruce 42	3
Bruce 43	2
Bruce 45	5
Bruce 55	1

Le Fleche *et al.*, BMC Microbiol, 2006

MLVA typing of Marine Mammal *Brucella* spp.

MLVA-16 typing of 170 marine mammal *Brucella* isolates from different animal and geographic origins identifies 5 major groups within *Brucella ceti* and *Brucella pinnipedialis*

Maquart M., Le Flèche P., Foster G., Tryland M., Ramisse F., Djønne B., Al Dahouk S., Jacques I., Neubauer H., Walravens K., Godfroid J., Cloeckaert A., Vergnaud G. 2009. MLVA-16 typing of 295 marine mammal Brucella isolates from different animal and geographic origins identifies 7 major groups within Brucella ceti and Brucella pinnipedialis. BMC Microbiol., 9:145.


Brucella ceti
ST26
ST23
ST27
ST24
ST25
Brucella pinnipedialis
harbour seal
human
AWSD
hooded seal
striped dolphin
gray seal
minke whale
bottlenose dolphin
common dolphin
white-beaked dolphin
otter
porpoise

First isolation of *Brucella ceti* in a stranded porpoise in Belgium in 2008

Isolation of *Brucella* sp. from lung and brain

Purification of DNA ⟶ MLVA analysis

David Fretin, CERVA
Thierry Jauniaux, Ulg

MARKER	Number of repeat
Bruce 04	6
Bruce 06	2
Bruce 07	6
Bruce 08	5
Bruce 09	3
Bruce 11	8
Bruce 12	7
Bruce 16	7
Bruce 18	4
Bruce 21	9
Bruce 30	6
Bruce 42	3
Bruce 43	2
Bruce 45	5
Bruce 55	1

B. ceti

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veterinary microbiology

www.elsevier.com/locate/vetmic

Prevalence of *Brucella pinnipediae* in healthy hooded seals (*Cystophora cristata*) from the North Atlantic Ocean and ringed seals (*Phoca hispida*) from Svalbard

Morten Tryland[a,*], Karen Kristine Sørensen[b,1], Jacques Godfroid[c,2]

[a]*Section of Arctic Veterinary Medicine, Department of Food Safety and Infection Biology, The Norwegian School of Veterinary Science, P.O. Box 6204, NO-9292 Tromsø, Norway*
[b]*National Veterinary Institute Tromsø, NO-9292 Tromsø, Norway*
[c]*Department of Bacteriology, Veterinary and Agrochemical Research Centre, Groeselenberg 99, 1180 Brussels, Belgium*

Received 6 May 2004; received in revised form 1 October 2004; accepted 22 October 2004

Table 2
Correlation between isolation of *Brucella pinnipediae* from organ samples ($n = 174$) and the presence of anti-*Brucella* antibodies in serum from 29 hooded seals (*Cystophora cristata*) caught between Svalbard and Greenland, autumn 2002 (only seropositive and/or culture positive individuals are presented; open spaces indicate no growth of *Brucella* or seronegative results

Animal number	Age (months)[a]	Sex	Tonsil	Lung	Lung lymph node	Spleen	Liver	Kidney	Testicle	Serology
1	6	M			NI[b]					+
8	30	F								+
9	6	F			+	+				+
17	30	M	+	+	+	+	+	+	+	+
22	6	M		+	+	+	+			+
23	6	F	+	+	+	+	+			
24	18	M	+			+			+	
25	18	M			+	+				+
30	18	M			+	+	+			+
37	6	M	+	+	+	+	+	+	NI[b]	+
38	6	F						+		
39	18	F			+	+	+			+
53	6	M			+					
Positive/tested			4/26	4/29	9/24	9/29	6/29	3/29	2/9	9/29
(%)			15	14	38	31	21	10	22	31

[a] Since birth takes place in March and the animals were caught in September, ages registered as <1 year corresponds to 6 months, 1–2 years to 18 months, 2–3 years to 30 months, and 3–4 years to 42 months.
[b] Not investigated.

Abortion during the first gestation is a core clinical symptom of *Brucella* sp. infections in terrestrial mammalian species, resulting in an increased age at first viable parturition. Abortion has also been described in bottlenose dolphins

Hooded seal population dynamics

Despite reduced hunting, model runs using recent pup production estimates as input suggest that the Greenland Sea hooded seal population has decreased substantially since the 1950s, and stabilized at a low level (10-15% of the 1946-level) since the 1970s (58, 98). Aerial surveys suggested a minimum pup production of 24 000 in 1997 and 15-16 000 in 2005 and 2007 (98, 138). Thus, current pup production in the Greenland Sea is considerably lower than in 1997 and no commercial hunting quotas have been issued for hooded seals in the Greenland Sea since 2006

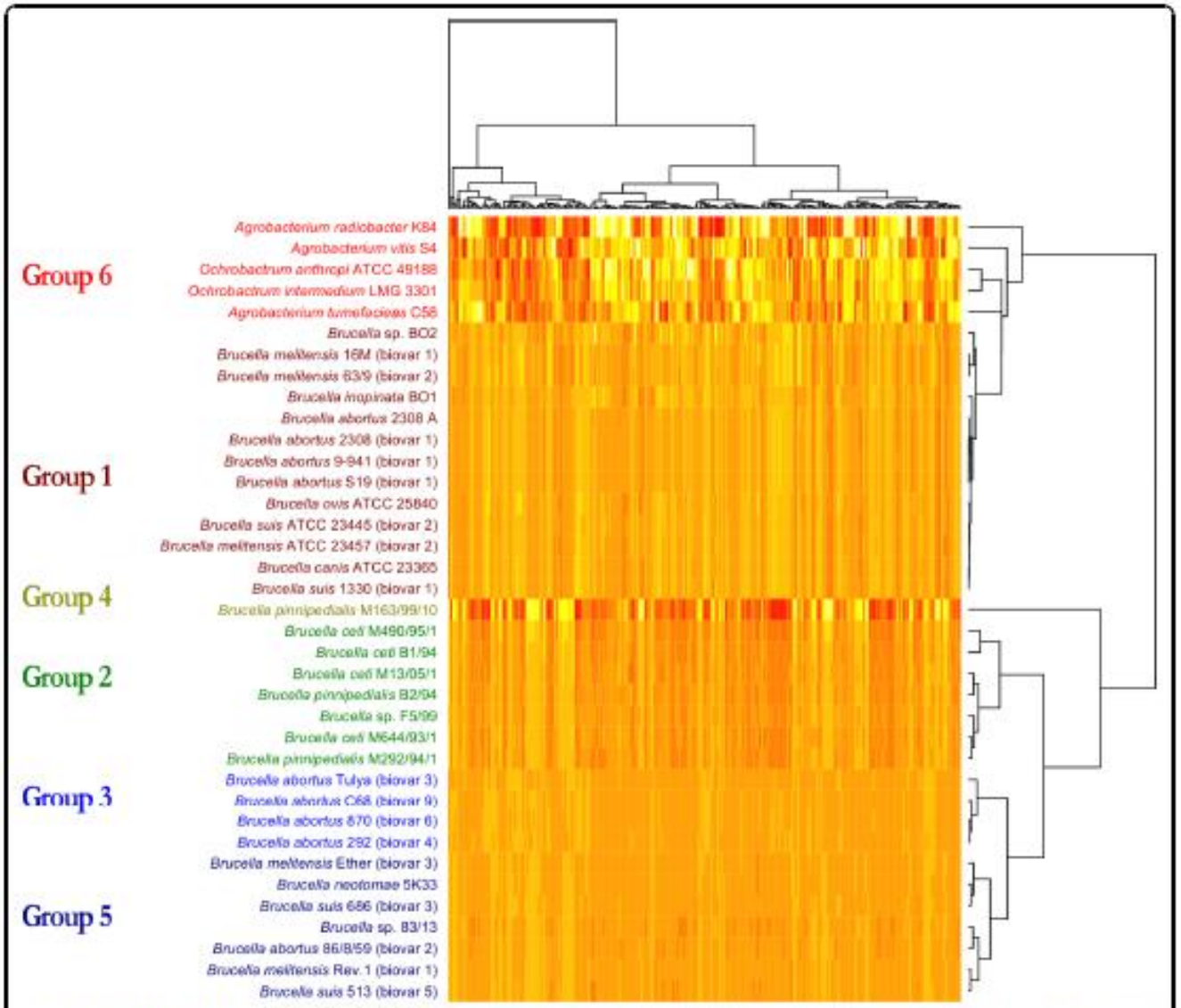


Figure 1 ZOM based heatmap. The ZOM Based heatmap shows all genomes compared using cluster analysis based on 0^{th} order Markov chain model predicted tetranucleotide frequencies. It can be seen that the sequenced species from genus *Brucella* are very similar in terms of tetranucleotide usage patterns, with larger differences found in the more distantly related genera of *Agrobacterium* and *Ochrobactrum*. Although all species in genus *Brucella* are very similar in terms of base composition, as measured using the ZOM based method, several subgroups can be observed. For instance, marine associated (Groups 2 and 4) and terrestrial mammal associated (Groups 1, 3 and 5) species of genus *Brucella* are segregated into different groups.

Naturally-occurring Human *Brucella* Infections

- **Neurobrucellosis - California (Sohn *et al*., 2002)**
  - **2 Peruvians - intracerebral granuloma**
  - **No link to marine mammals**
- **Spinal osteomyelitis - New Zealand (McDonald et al., 2006)**
  - **No reported link to marine mammals**
  - **Exposure to uncooked fish bait**
  - **Consumed raw fish**


CANADA
Queen Elizabeth Islands
ARCTIC
North pole
OCEAN
RUSSIA
Kara Sea
Baffin Bay
Greenland (Dk.)
SVALBARD
Barents Sea
Greenland Sea
Nuuk
Murmansk
Arkhangelsk
Iceland
Norwegian Sea
Finland
Reykjavik
Sweden
Norway
Saint Petersburg
Moskva (Moscow)
Helsinki
Stockholm
Minsk
Belarus
ATLANTIC OCEAN
North Sea
Ireland
United Kingdom
Poland
Ukraine

Extended ecological niche

Tryland M., Derocher A. E., Wijg O., Godfroid J., 2001. *Brucella* antibodies in polar bears (*Ursus maritimus*) from Svalbard and the Barents sea. Journal of Wildlife Disease, 37: 523-531.

Photo: Morten Tryland

Brucellosis in polar bear: new data or info ?

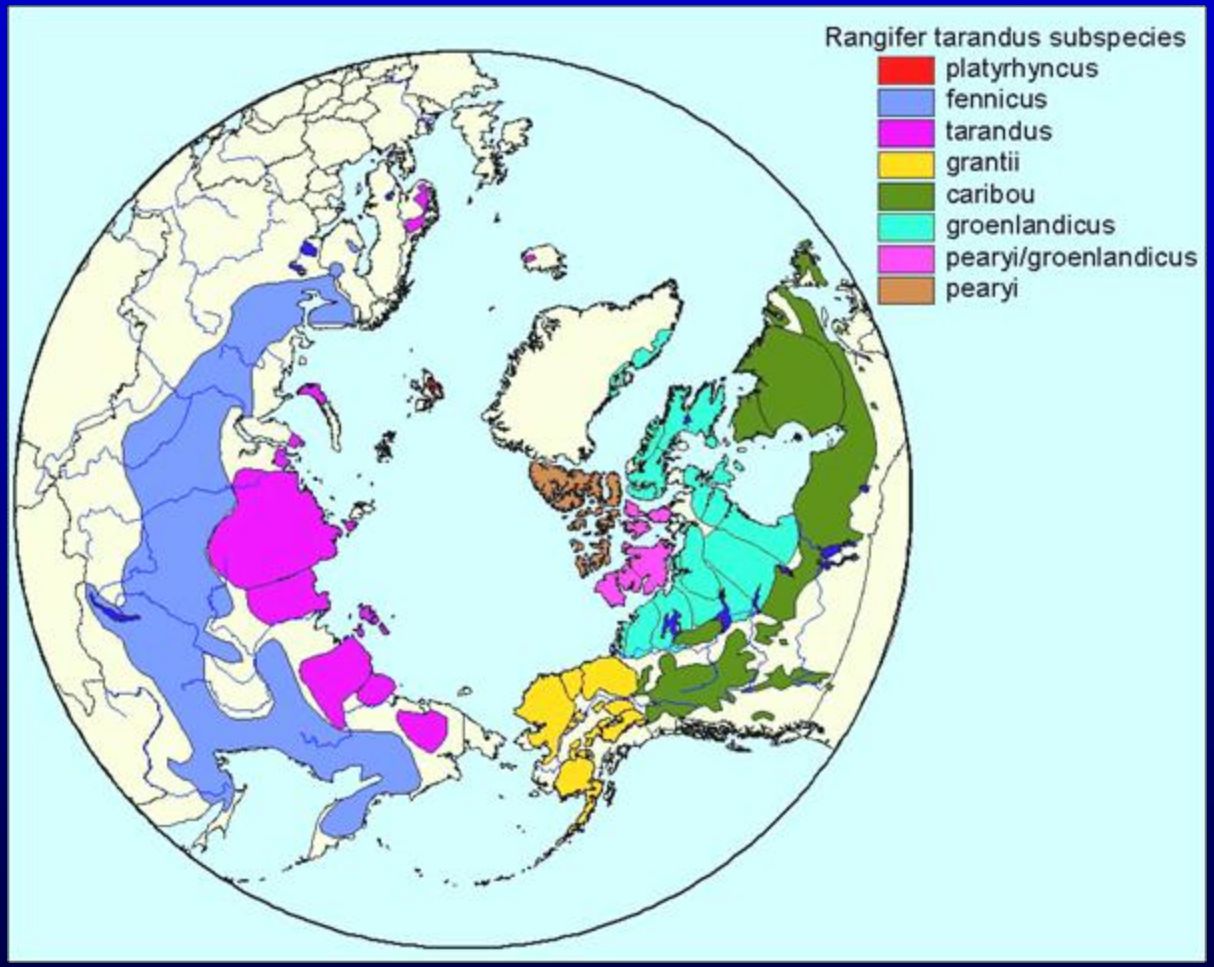
- ***Brucella*** **species survey in polar bears (*Ursus maritimus*) of northern Alaska. O'Hara TM, Holcomb D, Elzer P, Estepp J, Perry Q, Hagius S, Kirk C. J Wildl Dis. 2010 Jul;46(3):687-94.**

  Wildlife Toxicology Laboratory, Institute of Arctic Biology and Department of Biology and Wildlife, University of Alaska Fairbanks, Fairbanks, Alaska 99775, USA.

- **" It appears the polar bear antibody does not react with the antigens used on the marine cELISA assay, potentially indicating a terrestrial (nonpinniped) source of *Brucella* spp. "**

Political Arctic

Rangifer tarandus subspecies distribution




Biovars 1 & 3
Biovar 2


Brucella suis
Biovar 4


!

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Veterinary Microbiology 131 (2008) 376–385

www.elsevier.com/locate/vetmic

Short communication

Brucella suis identification and biovar typing by real-time PCR

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SNPs signatures

Pstp (1677)	PyrH (816/817)	MalG (954/963)	
A	GT	TC	→ *B. suis* 1
G	AG	TC	→ *B. suis* 2
A	AG	TC	→ *B. suis* 3,4
G	AG	CT	→ *B. suis* 5

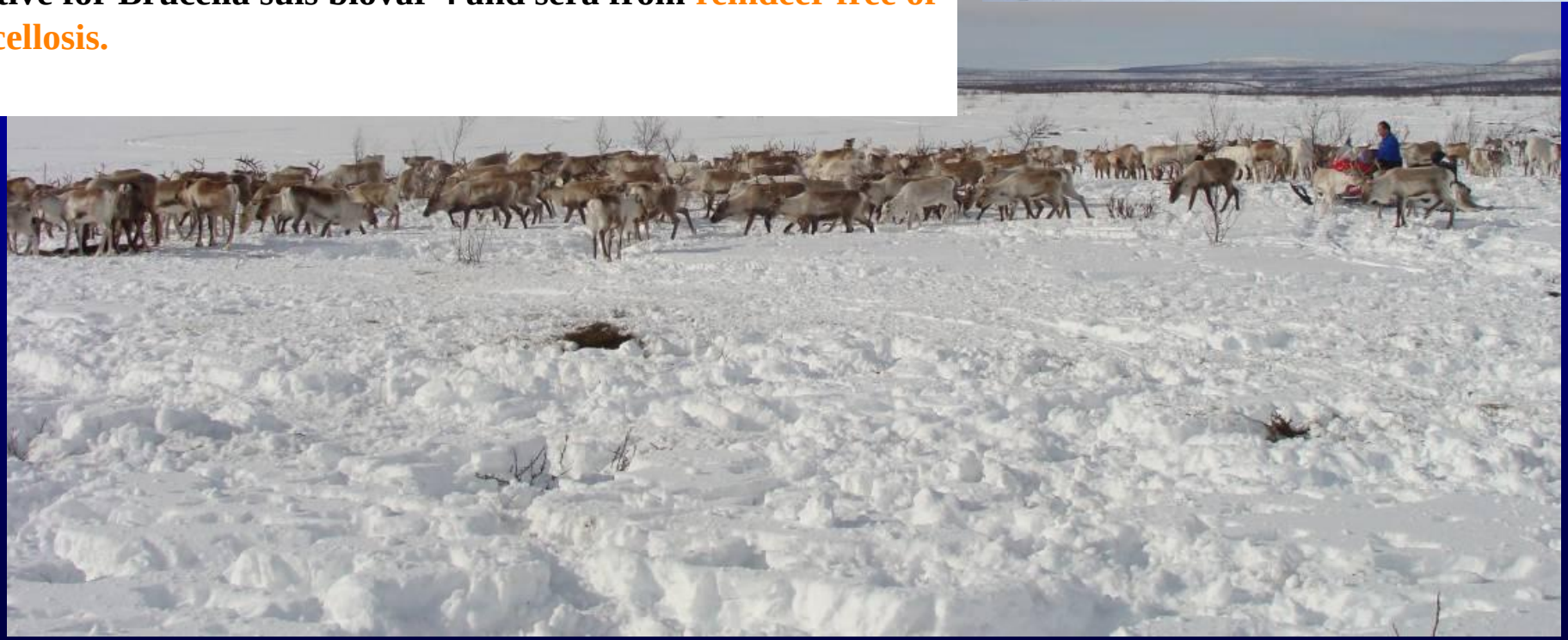
Brucellosis (*Brucella suis* biovar 4) in reindeer

Kautokeino


Nordkapp
Mehamn
Kjøllefjord
Berlevåg
Honningsvåg
Båtsfjord
Vardø
Hammerfest
Skáidi
Tana bru
Hasvik
Vadsø
Øksfjord
Rásttigáisá
1067
Kirkenes
Lakselv
Skjervøy
Alta
RUSSLAND
Sørkjosen
Storslett
Tromsø
Karasjok
NORDREISA
Skibotn
Gryllefjord
Andenes
Finnsnes
Kautokeino
FINLAND
Risøyhamn
Bardufoss
Harstad
Sortland
Lødingen
Narvik
Svolvær
Stamsund
SVERIGE


ALTA
NORDKAPP 210
OSLO 2010
TRONDHEIM 1465
BORIS GLEB 535
KIRUNA 458
HAMBURG 2564
KIRKENES 527
BEOGRAD 3782

A screening ELISA for brucellosis in reindeer.
Zentralbl Veterinarmed B. 1999 Nov;46(9):649-57.
Asbakk K, Gall D, Stuen S.
Norwegian School of Veterinary Science, Department of Arctic Veterinary Medicine, Tromsø, Norway.
Abstract
An enzyme-linked immunosorbent assay (ELISA) for the screening of brucellosis in reindeer was developed. The assay, which utilizes s-LPS from Brucella abortus as antigen and biotin-labelled rabbit antibody to reindeer immunoglobulin as detecting antibody, has a high specificity and sensitivity, as indicated in a validation with sera from reindeer cultured positive for Brucella suis biovar 4 and sera from reindeer free of brucellosis.



« The basis of the Nenets way of life is reindeer herding. Reindeer mean EVERYTHING to Nenets -- food, clothing, transportation. We are nomads, and the reindeer are so important to our way of life that they are almost like part of our families! Groups of reindeer numbering up to several hundred are owned by each extended family group. »

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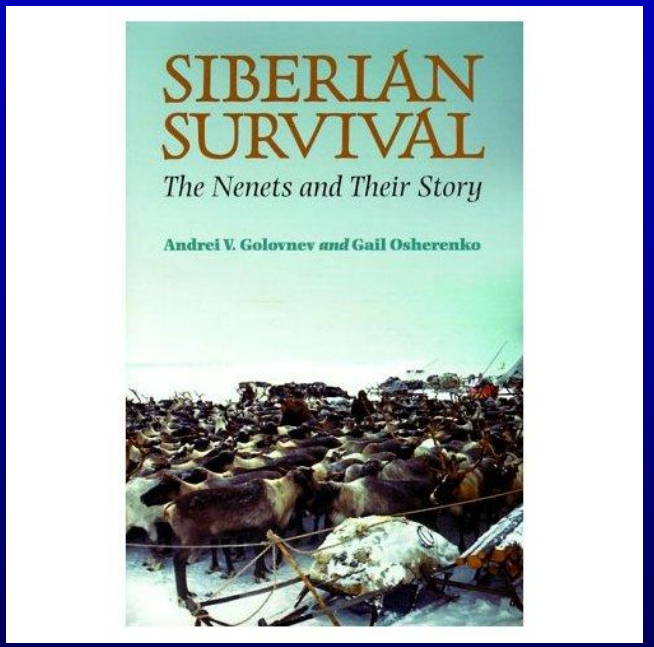
Brucellosis a zoonotic disease of concern…

« The reindeer are vaccinated against diseases, especially against brucellosis. »



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Brucellosis – Reindeer – Alaska / Canada

GEOGRAPHIC PATTERN OF SERUM ANTIBODY PREVALENCE FOR *BRUCELLA* SPP. IN CARIBOU, GRIZZLY BEARS, AND WOLVES FROM ALASKA, 1975–1998

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[2] Current address: NOAA National Marine Mammal Lab, 7600 Sand Point Way NE, Bldg 4, Seattle, Washington 98115-6349, USA
[3] Corresponding author (email: ltrap2@acsalaska.net)

ABSTRACT: Blood samples were collected from 2,635 caribou (*Rangifer tarandus*), 1,238 grizzly bears (*Ursus arctos*), and 930 wolves (*Canis lupus*) from throughout mainland Alaska during 1975–98. Sera were tested for evidence of exposure to *Brucella* spp. Serum antibody prevalences were highest in the northwestern region of the state. In any specific area, antibody prevalences for caribou and wolves were of a similar magnitude, whereas antibody prevalence for bears in these same areas were two to three times higher.

Key words: Alaska, *Brucella* spp., caribou, grizzly bear, wolf.

RANGIFERINE BRUCELLOSIS ON BAFFIN ISLAND

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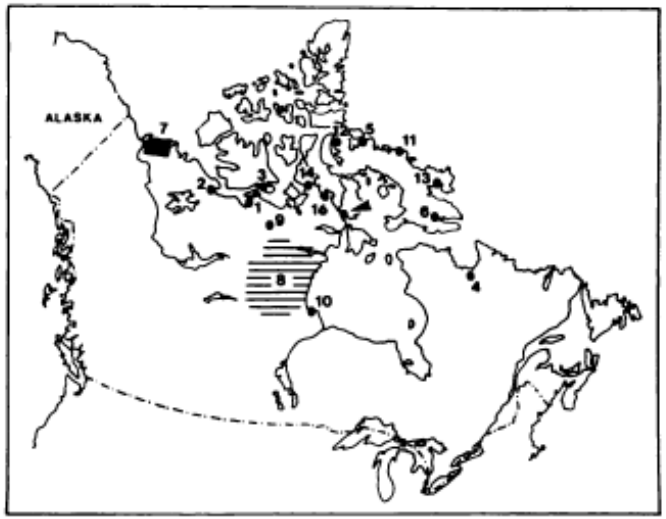
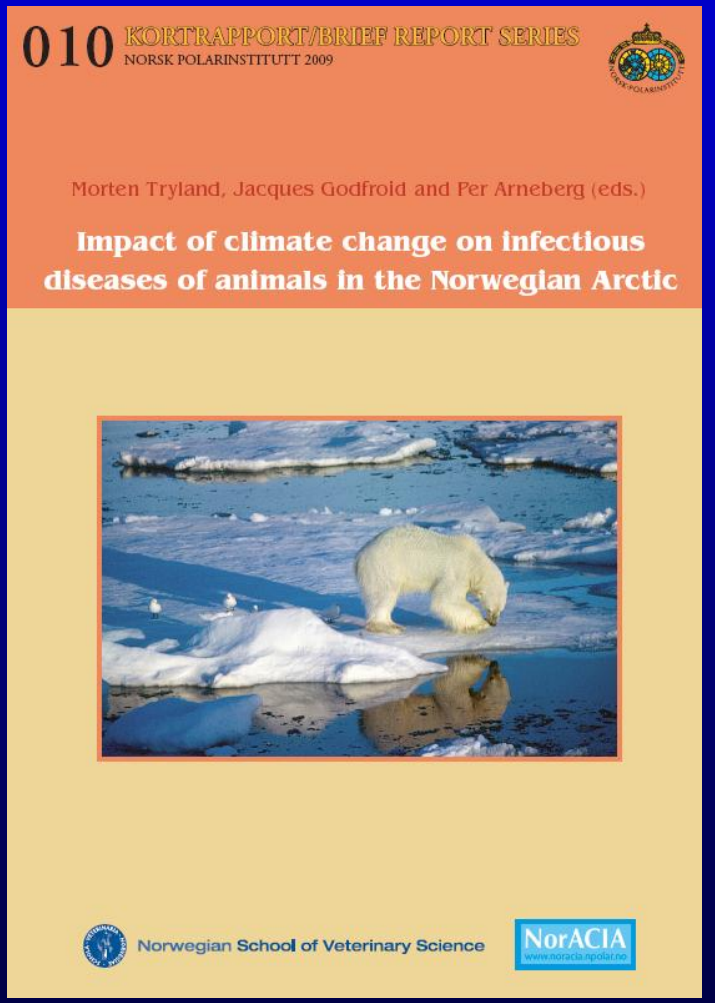
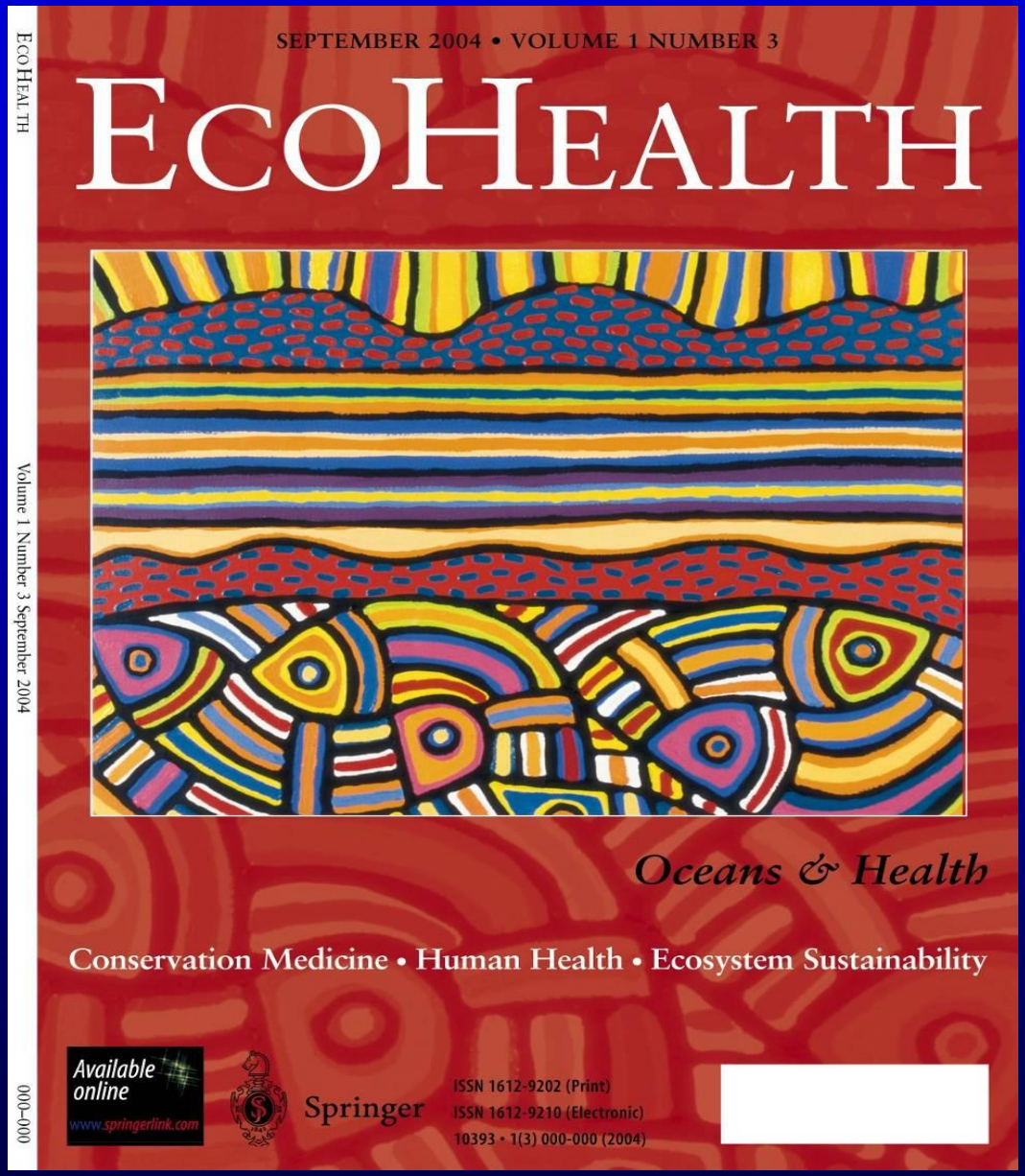


FIGURE 2. Location of reported instances of brucellosis in northern Canada. Numbers correspond to the cases listed in Table 1. The arrow indicates Repulse Bay, the location of the case of granulomatous nephritis in a barren ground caribou and of case number 15 in Table 1.

Climate change and infectious diseases of animals in the Arctic



Alonso Aguirre,
VP for Conservation Medicine



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The origin of brucellosis

In terrestrial mammals

Thank you for your attention