

# Veterinary World

## Editor-in-Chief

Anjum V. Sherasiya - Ex-Veterinary Officer, Department of Animal Husbandry, Gujarat State, India.

## Editorial board

- Shambhunath Choudhary - Veterinary Pathologist II, Pathology | Charles River Laboratories, 640 North Elizabeth Street, Spencerville, OH 45887, USA.
- Suresh H. Basagoudanavar - FMD Vaccine Research Laboratory, Indian Veterinary Research Institute, Bangalore- 560024, Karnataka, India.
- R. G. Jani - Ex-Coordinator of Wildlife Health, Western Region Centre, Indo-US Project, Department of Veterinary Medicine, Veterinary College, Anand Agricultural University, Anand - 388001, Gujarat, India.
- G. N. Gongal - WHO South -East Asia Regional Office, New Delhi -110002, India.
- Md. Tanvir Rahman Department of Microbiology and Hygiene, Faculty of Veterinary Science, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh.
- Deepmala Agarwal - Cancer Prevention Laboratory, Pennington Biomedical Research Center, Baton Rouge, LA, USA.
- Fouad Kasim Mohammad - Department of Pharmacology & Toxicology, Vice President for Administrative & Financial Affairs, University of Mosul, P.O. Box 11136, Mosul, Iraq.
- Nicole Borel - Department of Pathology, Vetsuisse Faculty, University of Zurich, CH-8057 Zurich, Switzerland.
- B. A. Lubisi - Virology, MED Programme, ARC - Onderstepoort Veterinary Institute, No. 100 Old Soutpan Road, Onderstepoort, Tshwane, 0110, South Africa.
- Kumar Venkitanarayanan - Graduate Programs Chair, Honors and Pre-Vet Programs Advisor, Department of Animal Science, University of Connecticut, Storrs, CT 06269, USA.
- Kemin Xu - Department of Veterinary Medicine, University of Maryland, College Park College Park, MD, 20742, USA.
- Vassilis Papatsiros - Faculty of Veterinary Medicine, Department of Medicine (Porcine Medicine), University of Thessaly, Thessaly, Greece.
- K. P. Singh - School of Medicine and Dentistry, University of Rochester, Department of Environmental Medicine, Room: 4-6820, 601 Elmwood Avenue, Box-EHSC, Rochester, New York-14620, USA.
- Ashok K. Chockalingam - Division of Applied Regulatory Science, U.S. Food and Drug Administration, 10903, New Hampshire Avenue, Silver Spring, Maryland 20993, USA.
- Ashutosh Wadhwa - Center for Global Safe Water, Sanitation and Hygiene at Emory University, Hubert Department of Global Health, Rollins School of Public Health, Emory University, 1518 Clifton Rd. NE, Atlanta, GA 30322, USA.
- Luiz Otavio Pereira Carvalho - Laboratory of Immunomodulation and Protozoology, Oswaldo Cruz Institute, Ministry of health (Brazil), Pavilhao "108" - Sala: 09, Av. Brasil, 4365 - Manguinhos, Rio de Janeiro - RJ, CEP: 21040-360, Brazil.

- Mallikarjun Bidarimath - Cornell Stem Cell Program, Department of Biomedical Sciences, T2-012 Veterinary Research Tower, Cornell University, College of Veterinary Medicine, Ithaca, NY 14853-6401, USA.
- Chyer Kim - Virginia State University, Petersburg, VA, USA.
- Ionel D. Bondoc - Department of Public Health, Faculty of Veterinary Medicine Iasi, University of Agricultural Sciences and Veterinary Medicine Iasi, Romania.
- Filippo Giarratana - Department of Veterinary Medicine, University of Messina, Polo Universitario dell'Annunziata, 98168 Messina, Italy.
- Abdelaziz ED-DRA - Department of Biology, Faculty of Science, Moulay Ismail University, BP. 11201 Zitoune, Meknes, Morocco.
- Eduardo Jorge Boeri - Institute of Zoonosis Luis Pasteur, Buenos Aires, Argentina.
- Liliana Aguilar-Marcelino - CENID-PARASITOLOGIA VETERINARIA, Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias: Jiutepec, Morelos, Mexico.
- Guilherme Dias de Melo - Institut Pasteur, Paris, Ile-de-France, France.
- Anut Chantiratikul - Department of Agricultural Technology, Faculty of Technology, Mahasarakham University, Muang, Mahasarakham Province 44150 Thailand.
- Panagiotis E Simitzis - Department of Animal Breeding and Husbandry, Faculty of Animal Science and Aquaculture, Agricultural University of Athens, 75 Iera Odos, 11855, Athens, Greece.
- Bartosz Kieronczyk - Poznan University of Life Sciences, Poznan, Greater Poland, Poland.
- Mario Manuel Dinis Ginja - Department of Veterinary Sciences, Center for Research and Agro-Environmental and Biological Technologies, University of Tras-os-Montes and Alto Douro, Portugal
- Nuh Kilic - Department of Surgery, Faculty of Veterinary Medicine, Adnan Menderes University, Turkey.
- Hanna Markiewicz - Milk Examination Laboratory, Kazimierz Wielki University in Bydgoszcz, Poland.
- Kai Huang - University of Texas Medical Branch at Galveston, Galveston, TX, USA.
- N. De Briyne - Federation of Veterinarians of Europe, Brussels, Belgium.
- Hasan Meydan - Akdeniz University, Faculty of Agriculture, Antalya, Turkey.
- Suleyman Cilek - Kirikkale Universitesi, Kirikkale, kirikkale, Turkey.
- Rodrigo Alberto Jerez Ebensperger - University of Zaragoza, Spain.
- Joao Simoes - Universidade de Tras-os-Montes e Alto Douro, Vila Real, Portugal.
- Alberto Elmi - University Of Bologna, Ozzano dell'Emilia, Bologna, Italy.
- Parag Nigam - Department of Wildlife Health Management, Wildlife Institute of India, Dehradun, India.
- Ali Aygun - Selcuk Universitesi, Konya, Turkey.

Volume - 15

No.3

March-2022

ISSN: 0972-8988

EISSN: 2231-0916



Scopus: Citescore-2.6, SJR-0.550, SNIP-1.387

## Veterinary World is indexed in

Academic Journals Database, AGORA, AGRICOLA, AGRIS, CABI, CAS, DOAJ, EBSCO, ESCI - Thomson Reuters, Gale, Google Scholar, HINARI, Index Scholar, Indian Animal Science Abstracts, Indian Science Abstracts, JournalSeek, Open J-gate, ProQuest, PubMed, PubMed Central, SCOPUS, TEEAL

# Veterinary World

Open access and peer reviewed journal



## Editorial office

Veterinary World,  
Star, Gulshan Park,  
NH-8A, Chandrapur Road,  
Wankaner - 363621,  
Dist. Morbi, Gujarat, India  
Website: [www.veterinaryworld.org](http://www.veterinaryworld.org)  
E-mail: [editorveterinaryworld@gmail.com](mailto:editorveterinaryworld@gmail.com)

Printed and Published by Dr. Anjum V. Sherasiya on behalf of Veterinary World. Printed and Published at Star, Gulshan Park, N.H. 8A, Chandrapur Road, Wankaner-363621, Dist. Morbi, Gujarat, India.  
Editor-in-Chief: Dr. Anjum V. Sherasiya



# Veterinary World

Open access and peer reviewed journal



ISSN (Online): 2231-0916  
ISSN (Print): 0972-8988

- Home
- Editorial Board
- For authors
- FAQ
- For reviewers
- Archive
- Open access policy

ENHANCED BY Google



Online submission

### Volumes

- + Volume - 15 (2022)
- + Volume - 14 (2021)
- + Volume - 13 (2020)
- + Volume - 12 (2019)
- + Volume - 11 (2018)
- + Volume - 10 (2017)
- + Volume - 9 (2016)
- + Volume - 8 (2015)
- + Volume - 7 (2014)
- + Volume - 6 (2013)
- + Volume - 5 (2012)
- + Volume - 4 (2011)
- + Volume - 3 (2010)
- + Volume - 2 (2009)
- + Volume - 1 (2008)

### Journal Ranking

SCOPUS (2018): 20/102 (2018)

### Latest articles

### All articles

### Most cited articles

**Research** (Published online: 30-09-2022)  
[Effect of honey bee venom on the histological changes of testes and hormonal disturbance in diabetic mice](#)  
 Sattar J. J. AL-Shaeli, Talal Jabal Hussien, and Ali M. Ethaeb  
 Veterinary World, 15(9): 2357-2364

Abstract PDF

**Research** (Published online: 30-09-2022)  
[Impact of hygiene and sanitation in ruminant slaughterhouses on the bacterial contamination of meat in Central Java Province, Indonesia](#)  
 Edy Dharma, Haryono Haryono, Aldi Salman, Pangesti Rahayu, and Widagdo Sri Nugroho  
 Veterinary World, 15(9): 2348-2356

Abstract PDF

**Research** (Published online: 29-09-2022)  
[Quality control procedure for Coccidial vaccines versus different routes of immunization](#)  
 Arwa Elnaggar, Hala Mahmoud, and Sahar Saber  
 Veterinary World, 15(9): 2342-2347

Abstract PDF

**Research** (Published online: 29-09-2022)  
[Effectiveness of Indonesian house dust mite allergenic extract in triggering allergic rhinitis sensitivity in a mouse model: A preliminary study](#)

### Aims and Scope

Veterinary World publishes high quality papers focusing on Veterinary and Animal Science. The fields of study are bacteriology, parasitology, pathology, virology, immunology, mycology, public health, biotechnology, meat science, fish diseases, nutrition, gynecology, genetics, wildlife, laboratory animals, animal models of human infections, prion diseases and epidemiology. Studies on zoonotic and emerging infections are highly appreciated. Review articles are highly appreciated. All articles published by Veterinary World are made freely and permanently accessible online. All articles to Veterinary World are posted online immediately as they are ready for publication.

### Indexed By

- Academic Journals Database
- AGORA
- AGRICOLA
- AGRIS
- CABI
- CAS
- DOAJ
- EBSCO



## Open Access

**Review** (Published online: 10-03-2022)

### 6. Experimental and natural infections of severe acute respiratory syndrome-related coronavirus 2 in pets and wild and farm animals

Gondo Mastutik, Ali Rohman, Reny I'tishom, Ignacio Ruiz-Arrondo and Ignacio de Blas  
Veterinary World, 15(3): 565-589

**Gondo Mastutik:** Department of Anatomic Pathology, Faculty of Medicine, Universitas Airlangga, Surabaya 60131, Indonesia.

**Ali Rohman:** Department of Chemistry, Faculty of Science and Technology, Universitas Airlangga, Surabaya 60115, Indonesia.

**Reny I'tishom:** Department of Medical Biology, Faculty of Medicine, Universitas Airlangga, Surabaya 60131, Indonesia.

**Ignacio Ruiz-Arrondo:** Center for Rickettsioses and Arthropod-Borne Diseases, Hospital Universitario San Pedro-CIBIR, Logroño, Spain.

**Ignacio de Blas:** Department of Animal Pathology, Faculty of Veterinary Sciences, Instituto Universitario de Investigación Mixto Agroalimentario de Aragón (IA2), Universidad de Zaragoza, Spain.



Download PDF Here

Citations

1

doi: [www.doi.org/10.14202/vetworld.2022.565-589](http://www.doi.org/10.14202/vetworld.2022.565-589)

Share this article on [\[Facebook\]](#) [\[LinkedIn\]](#)

**Article history:** Received: 19-10-2021, Accepted: 25-01-2022, Published online: 10-03-2022

**Corresponding author:** Gondo Mastutik

E-mail: [gondomastutik@fk.unair.ac.id](mailto:gondomastutik@fk.unair.ac.id)

**Citation:** Mastutik G, Rohman A, I'tishom R, Ruiz-Arrondo I, de Blas I (2022) Experimental and natural infections of severe acute respiratory syndrome-related coronavirus 2 in pets and wild and farm animals, *Veterinary World*, 15(3): 565-589.

## ABSTRACT

The severe acute respiratory syndrome-related coronavirus 2 (SARS-CoV-2) has spread globally and has led to extremely high mortality rates. In addition to infecting humans, this virus also has infected animals. Experimental studies and natural infections showed that dogs have a low susceptibility to SARS-CoV-2 infection, whereas domesticated cats and other animals in the family Felidae, such as lions, tigers, snow leopards, and cougars, have a high susceptibility to viral infections. In addition, wild white-tailed deer, gorillas, and otters have been found to be infected by SARS-CoV-2. Furry farm animals, such as minks, have a high susceptibility to SARS-CoV-2 infection. The virus appears to spread among minks and generate several new mutations, resulting in increased viral virulence. Furthermore, livestock animals, such as cattle, sheep, and pigs, were found to have low susceptibility to the virus, whereas chicken, ducks, turkeys, quail, and geese did not show susceptibility to SARS-CoV-2 infection. This knowledge can provide insights for the development of SARS-CoV-2 mitigation strategies in animals and humans. Therefore, this review focuses on experimental (both replication and transmission) *in vitro*, *ex vivo*, and *in vivo* studies of SARS-CoV-2 infections in pets and in wild and farm animals, and to provide details on the mechanism associated with natural infection.

## Editor-in-Chief

**Anjum V. Sherasiya** - Ex-Veterinary Officer, Department of Animal Husbandry, Gujarat State, India  
<https://orcid.org/0000-0002-1598-1820>

## Founding Associate Editor

**R. G. Jani** - Ex-Coordinator of Wildlife Health, Western Region Centre, Indo-US Project, Department of Veterinary Medicine, Veterinary College, Anand Agricultural University, Anand - 388001, Gujarat, India.

## Associate Editors

**B. A. Lubisi** - Virology, MED Programme, ARC - Onderstepoort Veterinary Institute, No. 100 Old Soutpan Road, Onderstepoort, Tshwane, 0110, South Africa  
Google Scholar profile: <https://scholar.google.com/citations?user=Wwcc5-8AAAAJ&hl=en>  
Interest area: Virology

**Girija Regmi** - Department of Cardiovascular Biology, Oklahoma Medical Research Foundation, Oklahoma City, Oklahoma, USA  
<https://orcid.org/0000-0001-6827-3783>  
Google Scholar profile: <https://scholar.google.com/citations?user=JRhk5-sAAAAJ&hl=en>  
Interest area: Anatomy - Animal Hygiene, Husbandry, Nutrition, and Food Control - Animal Nutrition - Animal Reproduction - Animal Science - Antimicrobial resistance - Bacteriology - Biological Sciences - Biomedical Sciences - Hematology - Immunohistochemistry - Microbiology - Molecular Biology - Veterinary Anatomy, Histology, and Physiology - Veterinary Medicine - Veterinary Medicine and Infectious Diseases - Veterinary Pathology - Veterinary Science - Zoonoses

**Widya Paramita Lokapirnasari** - Professor, Department of Animal Husbandry, Airlangga University, FKH, Kampus C Unair, Jl Mulyorejo, Surabaya, Indonesia  
<https://orcid.org/0000-0002-0319-7211>  
Google Scholar profile: <https://scholar.google.co.id/citations?user=eS3yVQQAAAAJ&hl=id>  
Interest area: Animal Nutrition - Cattle Husbandry - Feed Supplements - Polymerase Chain Reaction - Poultry Husbandry - Probiotics

**Ayman Abdel-Aziz Swelum** - Professor of Theriogenology, Faculty of Veterinary Medicine, Zagazig University, Zagazig, Egypt; Department of Animal Production, College of Food and Agriculture Sciences, King Saud University, Riyadh, Saudi Arabia  
<http://orcid.org/0000-0003-3247-5898>  
Google Scholar profile: <https://scholar.google.com/citations?user=OZTI3poAAAAJ&hl=en>  
Profile: <http://www.staffdata.zu.edu.eg/en/ShowData/18313>  
<https://faculty.ksu.edu.sa/ar/aswelum>  
Interest area: Animal Reproduction - Animal Production - Embryo transfer -

**Mario Manuel Dinis Ginja** Department of Veterinary Sciences, Center for Research and Agro-Environmental and Biological Technologies, University of Tras-os-Montes and Alto Douro, Portugal  
<https://orcid.org/0000-0002-0464-7771>  
Publons profile: <https://publons.com/researcher/1180094/mario-manuel-dinis-ginja/>  
Interest area: Orthopaedics - Radiology (Diagnostic) - Sonography - Veterinary Medicine - Veterinary Science

---

**Panagiotis E Simitzis** - Laboratory of Animal Breeding and Husbandry, Department of Animal Science, Agricultural University of Athens, 75 Iera Odos, 11855, Athens, Greece  
<http://orcid.org/0000-0002-1450-4037>  
Google Scholar profile: <https://scholar.google.com/citations?user=14F6cAQAAAAJ&hl=en>  
Interest area: Dietary Antioxidants - Feed Supplements - Animal Behaviour - Animal Welfare - Livestock Management - Poultry Husbandry - Sheep Husbandry - Swine Husbandry - Products' Quality Assessment

---

**Gul Ahmad** - Associate Professor of Biology (Tenured), Department of Natural Sciences, School of Arts & Sciences, Peru State College, Peru, Nebraska 68321, USA  
Google Scholar profile: <https://scholar.google.com/citations?user=WOIDNKUAAAAJ&hl=en>

---

**Bartosz Kieronczyk** - Poznan University of Life Sciences, Poznan, Greater Poland, Poland  
<https://orcid.org/0000-0001-6006-117X>  
Google Scholar profile: <https://scholar.google.pl/citations?user=SyprUmAAAAJ&hl=en>  
Interest area: Animal Nutrition - Animal Science - Antimicrobial resistance - Aquaculture - Feed Supplements - Livestock Management - Livestock Products Technology - Microbiology - Physiology - Poultry Science - Waste Management of Agro Products

---

**Alberto Elmi** - University of Bologna, Ozzano dell'Emilia, Bologna, Italy  
<https://orcid.org/0000-0002-7827-5034>  
Google Scholar profile: <https://scholar.google.it/citations?user=ej4LzNgAAAAJ&hl=it>  
Interest area: Animal Reproduction - Laboratory Animal Research - Laboratory Medicine - Physiology - Swine Medicine - Wildlife

---

## Editorial board

**Suresh H. Basagoudanavar** - FMD Vaccine Research Laboratory, Indian Veterinary Research Institute, Bangalore- 560024, Karnataka, India  
<https://orcid.org/0000-0001-7714-3120>  
ResearchGate profile: <https://www.researchgate.net/profile/Suresh-Basagoudanavar>  
Interest area: Biotechnology - Immunology - Virology

---

**Gyanendra Gongal** - Senior Public Health Officer (Food safety, zoonoses and One Health). World Health Emergency Programme, WHO Regional Office for

south East Asia, New Delhi, India

<https://orcid.org/0000-0002-6539-7569> Google Scholar profile:

<https://scholar.google.com/citations?user=XNCypDcAAAAJ&hl=en>

Interest area: Public Health - Zoonoses - One Health

---

**Md. Tanvir Rahman** - Department of Microbiology and Hygiene, Faculty of Veterinary Science, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh

<https://orcid.org/0000-0001-5432-480X>

Google Scholar profile: <https://scholar.google.com>

[/citations?user=vp6xgh0AAAAJ&hl=en](https://scholar.google.com/citations?user=vp6xgh0AAAAJ&hl=en)

Interest area: Antimicrobial resistance - Virulence-Food hygiene- Public Health - Vaccine - One Health

---

**Fouad Kasim Mohammad** - Professor Emeritus, Pharmacology & Toxicology, College of Veterinary Medicine, University of Mosul, Mosul, Iraq

Google Scholar profile: <https://scholar.google.com>

[/citations?user=zgCIA4UAAAAJ&hl=en](https://scholar.google.com/citations?user=zgCIA4UAAAAJ&hl=en)

Interest area: Pharmacology - Toxicology

---

**Joao Simoes** - Universidade de Tras-os-Montes e Alto Douro, Vila Real, Portugal

<https://orcid.org/0000-0002-4997-3933>

Google Scholar profile: <https://scholar.google.com/citations?user=ftLFW-sAAAAJ&hl=en>

Interest area: Large Animal Medicine - Mastitis - Reproductive medicine - Veterinary Medicine

---

**Abdelaziz ED-DRA** - Department of Biology, Faculty of Science, Moulay Ismail University, BP. 11201 Zitoune, Meknes, Morocco

<https://orcid.org/0000-0003-3273-1767>

Google Scholar profile: <https://scholar.google.com/citations?user=ftL-1V0AAAAJ&hl=en>

Interest area: Antimicrobial resistance - Clinical Microbiology - Food - Food/Meat Hygiene - Polymerase Chain Reaction

---

**Filippo Giarratana** - Department of Veterinary Medicine, University of Messina, Polo Universitario dell'Annunziata, 98168 Messina, Italy

<https://orcid.org/0000-0003-0892-4884>

Google Scholar profile: <https://scholar.google.com/citations?user=lut-WbIAAAJ&hl=it>

Interest area: Antimicrobial resistance - Bacteriology - Food/Meat Hygiene - Plant Science - Essential oils

---

**Eduardo Jorge Boeri** - Institute of Zoonosis Luis Pasteur, Buenos Aires, Argentina

<https://orcid.org/0000-0001-8535-0306>

Google Scholar profile: <https://scholar.google.com>

[/citations?user=aerl\\_4oAAAAJ&hl=en&oi=sra](https://scholar.google.com/citations?user=aerl_4oAAAAJ&hl=en&oi=sra)

Interest area: Brucellosis - Microbiology - Veterinary Medicine - Veterinary Public Health - Zoonoses

---

**Kumar Venkitanarayanan** - Graduate Programs Chair, Honors and Pre-Vet Programs Advisor, Department of Animal Science, University of Connecticut, Storrs, CT 06269, USA

Google Scholar profile: <https://scholar.google.com/citations?hl=en&user=Nr9CY28AAAAJ>

Interest area: Bacteriology - Clinical Microbiology - Infectious Diseases -  
Veterinary Medicine

---

**Karim El-Sabrou** - Poultry Production Department, Alexandria University,  
Alexandria, Egypt

<https://orcid.org/0000-0003-2762-2363>

Google Scholar profile: <https://scholar.google.com/citations?hl=en&user=q-1jH8AAAAAJ>

Interest area: Poultry Husbandry

---

**Ali Aygun** - Selçuk University, Agriculture Faculty, Department of Animal  
Science, Konya, TURKEY

<https://orcid.org/0000-0002-0546-3034>

Google Scholar profile: <https://scholar.google.com/citations?hl=en&user=nZsp5iAAAAAJ>

Interest area: Poultry Husbandry - Poultry Medicine

---

**Ionel D. Bondoc** - Associate Professor, Department of Public Health, Faculty of  
Veterinary Medicine Iasi, University of Life Sciences "Ion Ionescu de la Brad"  
Iasi, Romania

<https://orcid.org/0000-0002-5958-7649>

Google Scholar profile: <https://scholar.google.ro/citations?user=-dUf6oYAAAAJ&hl=ro>

Publons Profile: <https://publons.com/researcher/741287/ionel-bondoc/>

Interest area: Dairy Science - Epidemiology - Food Science - Food Technology -  
Food Law - One Health - Parasitology - Meat Inspection - Pathogens -  
Foodborne Diseases - Food Toxicology - Veterinary Public Health - Wildlife  
Diseases - Zoonoses

---

**Liliana Aguilar-Marcelino** - National Center for Disciplinary Research in  
Animal Health and Safety, National Institute for Agricultural and Livestock  
Forestry Research, Mexico

<https://orcid.org/0000-0002-8944-5430>

Google Scholar profile: <https://scholar.google.ro/citations?hl=ro&user=ZbMMp-UAAAAJ>

Interest area: Biology - Ethnoveterinary - Parasitology - Veterinary Medicine -  
Veterinary Public Health

---

**Anut Chantiratikul** - Department of Agricultural Technology, Faculty of  
Technology, Mahasarakham University, Muang, Mahasarakham Province 44150  
Thailand

<https://orcid.org/0000-0002-8313-5802>

Google Scholar profile: <https://scholar.google.ro/citations?hl=ro&user=QogjWpgAAAAJ>

Interest area: Biology - Animal Nutrition

---

**Nuh Kilic** - Department of Surgery, Faculty of Veterinary Medicine, Adnan  
Menderes University, Turkey

<https://orcid.org/0000-0001-8452-161X>

Google Scholar profile: <https://scholar.google.ro/citations?hl=ro&user=APVrx1cAAAAJ>

Interest area: Large Animal Medicine - Surgery - Veterinary Medicine

---

**Hanna Markiewicz** - Milk Examination Laboratory, Kazimierz Wielki University  
in Bydgoszcz, Poland

<https://orcid.org/0000-0001-8225-0481>

ResearchGate profile: <https://www.researchgate.net/scientific-contributions/H-Markiewicz-10381112>

Interest area: Large Animal Medicine - Mastitis

---

**N. De Briyne** - Federation of Veterinarians of Europe, Brussels, Belgium

<https://orcid.org/0000-0002-2348-930X>

Google Scholar profile: <https://scholar.google.ro/citations?hl=ro&user=BOhfORAAAAAJ>

Interest area: Animal Science - Antimicrobial resistance

---

**Hasan Meydan** - Akdeniz University, Faculty of Agriculture, Antalya, Turkey

<https://orcid.org/0000-0003-4681-2525>

Google Scholar profile: <https://scholar.google.ro/citations?hl=ro&user=T2uHga0AAAAJ>

Interest area: Biotechnology - Genetics - Veterinary Medicine

---

**Suleyman Cilek** - Kirikkale Universitesi, Kirikkale, kirikkale, Turkey

<https://orcid.org/0000-0002-2352-649X>

ResearchGate profile: <https://www.researchgate.net/scientific-contributions/Suleyman-Cilek-2092525513>

Interest area: Animal Nutrition - Animal Nutrition - Animal Reproduction - Animal Reproduction - Animal Reproduction - Breeding - Cattle Husbandry - Cattle/buffalo management - Equine Medicine - Genetics - Livestock Management - Mastitis - Molecular Genetics - Poultry Husbandry - Poultry Husbandry - Sheep Husbandry - Sheep Husbandry - Small Animal Medicine - Swine Husbandry - Veterinary Medicine

---

**Rodrigo Alberto Jerez Ebensperger** - University of Zaragoza, Spain

Interest area: Animal Reproduction - Artificial Insemination - Biotechnology - Breeding - Embryo Transfer Technology - Equine Medicine - Large Animal Medicine - Livestock Management - Small Animal Medicine - Veterinary Medicine - Wildlife

---

**Parag Nigam** - Department of Wildlife Health Management, Wildlife Institute of India, Dehradun, India

ResearchGate profile: <https://www.researchgate.net/profile/Parag-Nigam>

Interest area: Veterinary Medicine - Veterinary Public Health - Wildlife - Zoonoses

---

**Alessandra Pelagalli** - Department of Advanced Biomedical Sciences, University of Naples Federico II, Italy

<https://orcid.org/0000-0002-1133-4300>

Google Scholar profile: <https://scholar.google.ro/citations?hl=ro&user=T1iZqmMAAAAJ>

Interest area: Physiology

---

**Jamal Gharekhani** - Senior researcher, Iranian Veterinary Organization (IVO), Hamedan, Iran

<https://orcid.org/0000-0001-5882-8861>

Google Scholar profile: <https://scholar.google.ro/citations?hl=ro&user=vlhjoBEAAAAJ>

Interest area: Parasitology - Pathobiology - Veterinary Public Health

---

**Ipsita Mohanty** - Postdoctoral Research Fellow, Children's Hospital of Philadelphia Research Institute, (CHOP), Philadelphia

<https://orcid.org/0000-0003-0894-4770>



Google Scholar profile: <https://scholar.google.ro/citations?hl=ro&user=anWIO7IAAAAJ>

Interest area: Pharmacology - Toxicology - Physiology - Cardiology

---

**Alejandro Hidalgo** - Preclinical Science Department, Faculty of Medicine, Universidad de La Frontera, Temuco, Chile

<https://orcid.org/0000-0002-2247-4878>

Google Scholar profile: <https://scholar.google.ro/citations?hl=ro&user=5veJgSAAAAAJ>

Interest area: Zoonotic parasitic diseases - Parasite phylogeny - Zoology - Parasitology

---

**Hua-Ji Qiu** - Professor, Harbin Veterinary Research Institute (HVRI), Chinese Academy of Agricultural Sciences (CAAS), Harbin, Heilongjiang, 150069, P.R. China

<https://orcid.org/0000-0003-4880-5687>

Profile: [http://www.hvri.ac.cn/zzjg/cxtd/zlxzrbcxtd/sx\\_20180726100149743651/index.htm](http://www.hvri.ac.cn/zzjg/cxtd/zlxzrbcxtd/sx_20180726100149743651/index.htm)

Interest area: Classical swine fever - African swine fever - Pseudorabies - Innate and adaptive immunity - Virus-host interactions - Pathogenesis - Epidemiology - Vaccines - Diagnostic assays - Probiotics

---

**Hasria Alang** - Biology Lecturer at STKIP-PI Makassar, Makassar, Indonesia

<https://orcid.org/0000-0001-9393-9575>

Google Scholar profile: <https://scholar.google.ro/citations?hl=ro&user=NpwjancAAAAJ>

Interest area: Microbiology - Molecular Biology

---

**Belgin Siriken** - Professor, Department of Water Products Diseases, Faculty of Veterinary Medicine, Ondokuz Mayıs University, Kurupelit Campus, 55200 Samsun, Turkey

<https://orcid.org/0000-0002-5793-1792>

Google Scholar profile: <https://scholar.google.ro/citations?hl=ro&user=JpuWvaUAAAAJ>

Interest area: Food - Food science - Food Technology - Food borne diseases - Antibiotic resistance - One Health - Veterinary Public Health

---

**Hussein Awad Hussein** - Professor of Internal Veterinary Medicine, Department of Animal Medicine, Faculty of Veterinary Medicine, Assiut University, Assiut 71526, Egypt

<https://orcid.org/0000-0003-0449-8283>

Google Scholar profile: <https://scholar.google.ro/citations?hl=ro&user=oJySPI8AAAAJ>

Interest area: Internal Medicine - Spectrophotometry - Ultrasonography - Parasitological analysis - Blood gas analysis - Metabolic profiling - Veterinary Medicine - Large Animal Medicine - Equine Medicine - Mastitis

---

**Tanko Polycarp Nwunuji** - Senior lecturer, Department of Veterinary Microbiology and Pathology, Faculty of Veterinary Medicine, University of Jos, Plateau State, Nigeria

<https://orcid.org/0000-0003-1459-2564>

Google Scholar profile: <https://scholar.google.ro/citations?hl=ro&user=MD7ehVwAAAAJ>

Interest area: Clinical and Anatomic Pathology - Oncology - Fisheries with special interest in bacterial diseases of fishes and other diseases associated

with aquaculture management - Diseases of small and large ruminants -  
Laboratory animal medicine - Diseases of Dogs, horses and pigs as well as non-  
infectious diseases such as Diabetes and stress-induced pathologies

---

**Md. Ahaduzzaman** - Associate Professor, Department of Medicine and  
Surgery, Faculty of Veterinary Medicine, Chittagong Veterinary and Animal  
Sciences University, Bangladesh

<https://orcid.org/0000-0002-0568-0506>

Google Scholar profile: [https://scholar.google.ro/citations?hl=ro&  
user=u6x\\_8FkAAAAJ](https://scholar.google.ro/citations?hl=ro&user=u6x_8FkAAAAJ)

Interest area: Antimicrobial resistance - Infectious Diseases - Poultry Medicine -  
Veterinary Medicine - Veterinary Microbiology and Parasitology - Veterinary  
Public Health - Veterinary Science - Meta-analysis - Phylogenetic analysis

---

**Vanessa S. Cruz** - Professor, Department of Veterinary Medicine, Catholic  
University Center of East Minas (Unileste), Avenue President Tancredo de  
Almeida Neves, 3500, University District, Coronel Fabriciano - MG, Brazil

<https://orcid.org/0000-0002-8914-5964>

Profile: <http://lattes.cnpq.br/8788967925940484>

Interest area: Cancer - Molecular Biology - Veterinary Medicine - Veterinary  
Pathology - Small Animal Clinic and Surgery (oncology, geriatrics, breeding and  
behavior of dogs and cats)

---

**R.Umaya Suganthi** - Principal Scientist, ICAR-National Institute of Animal  
Nutrition and Physiology (ICAR-NIANP), Government of India, Bangalore 560  
030, Karnataka, India

<https://orcid.org/0000-0002-7710-6271>

Google Scholar Profile: [https://scholar.google.co.in  
/citations?user=6VEZ7XMAAAJ&hl=en](https://scholar.google.co.in/citations?user=6VEZ7XMAAAJ&hl=en)

Interest area: Antimicrobial resistance - Antibiotic growth promoters in poultry  
and their alternatives - Phytochemicals - Oxidative stress and antioxidants -  
Mycotoxin toxicity and amelioration - Selenium and selenoproteins

---

Last updated on 23-03-2022

## Site Links

---

Editorial board (<http://www.veterinaryworld.org/editorial.html>)

Instruction for authors ([http://www.veterinaryworld.org  
/manuscript.html](http://www.veterinaryworld.org/manuscript.html))

Author declaration certificate ([http://www.veterinaryworld.org  
/author declaration certificate.pdf](http://www.veterinaryworld.org/author%20declaration%20certificate.pdf))

Tutorial for online submission ([http://my.ejmanager.com  
/scopemed\\_tutorial\\_authors.pdf](http://my.ejmanager.com/scopemed_tutorial_authors.pdf))

Manuscript template ([http://www.veterinaryworld.org  
/Manuscripttemplate.pdf](http://www.veterinaryworld.org/Manuscripttemplate.pdf))

Submit your manuscript (<http://my.ejmanager.com/vetworld/>)

FAQ (<http://www.veterinaryworld.org/FAQ.html>)

Reviewer guidelines ([http://www.veterinaryworld.org/Reviewer guideline.pdf](http://www.veterinaryworld.org/Reviewer%20guideline.pdf))

Open access policy (<http://www.veterinaryworld.org/subscription.html>)

Most cited articles (<http://scholar.google.co.in/citations?hl=en&authuser=1&>

user=vWiG7DoAAAAJ)

Archive (<http://www.veterinaryworld.org/tableofcontent.html>)

---

**Editorial Office**

Veterinary World Star, Gulshan Park, NH-8A, Chandrapur Road,

Wankaner - 363621, Dist. Morbi (Gujarat), India

E-mail: [editorveterinaryworld@gmail.com](mailto:editorveterinaryworld@gmail.com)

Website: [www.veterinaryworld.org](http://www.veterinaryworld.org)

---

**Editor-in-Chief**

Dr. Anjum V. Sherasiya

E-mail: [editorveterinaryworld@gmail.com](mailto:editorveterinaryworld@gmail.com)

---

**Publisher:** Veterinary World, E-mail: [veterinaryworldpublisher@gmail.com](mailto:veterinaryworldpublisher@gmail.com)

**Designed By** [Madni Infoway \(http://www.madniinfoway.com/\)](http://www.madniinfoway.com/)

---

# Veterinary World

---

ISSN: 0972-8988, EISSN: 2231-0916, [www.veterinaryworld.org](http://www.veterinaryworld.org)

---

**Volume-15**

**No.3**

**March-2022**

---

The articles in Veterinary World are open access articles licensed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The Creative Commons Public Domain Dedication waiver (<http://creativecommons.org/publicdomain/zero/1.0/>) applies to the data made available in this article, unless otherwise stated.

---

Reviewer Acknowledgment (Published online: 07-03-2022)

1. Veterinary World reviewer acknowledgment 2021 - A. V. Sherasiya and Nazir  
Veterinary World, 15(3): 531-536

Research (Published online: 08-03-2022)

2. Evaluation of the anesthetic depth and bispectral index during propofol sequential target-controlled infusion in dogs

Matheus Luis Cunha Ubiali, Guilherme Paes Meirelles, Julia Milczewski Vilani, Henrique Erick da Luz, Sabrine Marangoni, Raisa Brul Rodrigues and Ricardo Guilherme D'Octaviano de Castro Vilani  
Veterinary World, 15(3): 537-542

Research (Published online: 09-03-2022)

3. Risk factors associated with Salmonella prevalence, its antibiotic resistance, and egg antibiotic residues in the layer farming environment

Pairat Sornplang, Jareerat Aieamsaard, Chuleeporn Saksangawong and Naritsara Suayroop  
Veterinary World, 15(3): 543-550

Research (Published online: 09-03-2022)

4. Dehydrated husks and cake of prickly pear (*Opuntia ficus-indica*) processing for broiler feed: Effects on growth performance, carcass characteristics, and meat quality

Imene Cherif, Rafik Arbouche, Yasmine Arbouche, Achour Mennani and Fodil Arbouche  
Veterinary World, 15(3): 551-557

Research (Published online: 10-03-2022)

5. Genetic relationship of *Staphylococcus aureus* isolated from humans, animals, environment, and Dangke products in dairy farms of South Sulawesi Province, Indonesia

Sartika Juwita, Agustin Indrawati, Retno Damajanti, Safika Safika and Ni Luh Putu Ika Mayasari  
Veterinary World, 15(3): 558-564

Review (Published online: 10-03-2022)

6. Experimental and natural infections of severe acute respiratory syndrome-related coronavirus 2 in pets and wild and farm animals

Gondo Mastutik, Ali Rohman, Reny I'tishom, Ignacio Ruiz-Arrondo and Ignacio de Blas  
Veterinary World, 15(3): 565-589

Research (Published online: 12-03-2022)

7. Development of loop-mediated isothermal amplification-lateral flow dipstick as a rapid screening test for detecting *Listeria monocytogenes* in frozen food products using a specific region on the ferrous iron transport protein B gene

Wimvipa Srisawat, Chalermkiat Saengthongpinit and Wirawan Nuchchanart  
Veterinary World, 15(3): 590-601

Research (Published online: 12-03-2022)

8. Development and evaluation of indirect enzyme-linked immunosorbent assay using recombinant dense granule antigen 7 protein for the detection of *Toxoplasma gondii* infection in cats in Thailand

Eukote Suwan, Piangjai Chalermwong, Rucksak Rucksaken, Metita Sussadee, Sarawan Kaewmongkol, Ruenruetai Udonsom, Sathaporn Jittapalapong and Bandid Mangkit  
Veterinary World, 15(3): 602-610

---

---

Research (Published online: 18-03-2022)

9. Antimicrobial resistance of commensal *Enterococcus faecalis* and *Enterococcus faecium* from food-producing animals in Russia

Dmitry A. Makarov, Olga E. Ivanova, Anastasia V. Pomazkova, Maria A. Egoreva, Olga V. Prasolova, Sergey V. Lenev, Maria A. Gergel, Nataliya K. Bukova and Sergey Yu Karabanov

*Veterinary World*, 15(3): 611-621

Research (Published online: 19-03-2022)

10. Exploration of double-dart injection technique as a supplemental application for remote drug delivery system for zoo and wild animals

Rattapan Pattanarangsarn, Pawinee Kulnanan, Watcharapong Mitsuwan and Tuempong Wongtawan

*Veterinary World*, 15(3): 622-626

Research (Published online: 22-03-2022)

11. Effects of testosterone and exercise training on bone microstructure of rats

Catarina Jota-Baptista, Ana I. Faustino-Rocha, Margarida Fardilha, Rita Ferreira, Paula A. Oliveira, Marta Regueiro-Purriños, José A. Rodriguez-Altonaga, José M. Gonzalo-Orden and Mário Ginja

*Veterinary World*, 15(3): 627-633

Research (Published online: 22-03-2022)

12. Identification of *Streptomyces* spp. from garbage dump soils in Surabaya, Indonesia

R. Kurnijasanti and S. A. Sudjarwo

*Veterinary World*, 15(3): 634-639

Research (Published online: 23-03-2022)

13. Palatability assessment of prescribed diets on domestic shorthair cats

Nazhan Ilias, Ahmad Harris Hakim Zaki, Awang Hazmi Awang Junaidi, Lau Seng Fong, Ikhwan Saufi and Mokrish Ajat

*Veterinary World*, 15(3): 640-646

Research (Published online: 23-03-2022)

14. Study of fecal glucocorticoid metabolites in captive Asian elephants in Kanchanaburi Province, Thailand

Weerapun Nokkaew, Apiradee Intarapuk, Apichaya Sakulthai, Worawidh Wajjwalku and Nikorn Thongtip

*Veterinary World*, 15(3): 647-654

Research (Published online: 23-03-2022)

15. First identification of *Mycobacterium avium* subsp. *paratuberculosis* in wild ruminants in a zoo in Mexico

A. L. Hernández-Reyes, G. Chávez-Gris, E. Maldonado-Castro, L. E. Alcaraz-Sosa and M. T. Díaz-Negrete

*Veterinary World*, 15(3): 655-661

Review (Published online: 23-03-2022)

16. The public health issue of antibiotic residues in food and feed: Causes, consequences, and potential solutions

Mbarga Manga Joseph Arsène, Anyutoulou Kitio Linda Davares, Podoprigora Irina Viktorovna, Smolyakova Larissa Andreevna, Souadkia Sarra, Ibrahim Khelifi and Das Milana Sergueïevna

*Veterinary World*, 15(3): 662-671

Research (Published online: 24-03-2022)

17. Hematological indices and their correlation with glucose control parameters in a prediabetic rat model

Desak Gede Budi Krisnamurti, Erni H. Purwaningsih, Tri Juli Edi Tarigan, Vivian Soetikno and Melva Louisa

*Veterinary World*, 15(3): 672-678

Research (Published online: 24-03-2022)

18. Early hip laxity screening and later canine hip dysplasia development

Ana Santana, Sofia Alves-Pimenta, Pedro Franco-Gonçalo, Lio Gonçalves, João Martins, Bruno Colaço and Mário Ginja

*Veterinary World*, 15(3): 679-684

Review (Published online: 24-03-2022)

19. The application of ascorbic acid as a therapeutic feed additive to boost immunity and antioxidant activity of poultry in heat stress environment

Truong Van Hieu, Budi Guntoro, Nguyen Hoang Qui, Nguyen Thi Kim Quyen and Farid Akbar Al Hafiz

*Veterinary World*, 15(3): 685-693

---

Research (Published online: 24-03-2022)

20. Effect of probiotic and *Moringa oleifera* extract on performance, carcass yield, and mortality of Peking duck  
Widya Paramita Lokapirnasari, Bodhi Agustono, Mohammad Anam Al Arif, Lilik Maslachah, Evania Haris Chandra and Andreas Berny Yulianto  
*Veterinary World*, 15(3): 694-700

Research (Published online: 25-03-2022)

21. Systematic evaluation of TaqMan real-time polymerase chain reaction assays targeting the *dsb* and *gltA* loci of *Ehrlichia canis* in recombinant plasmids and naturally infected dogs  
Peeravit Sumpavong, Wanat Sricharern, Natnaree Inthong, Gunn Kaewmongkol and Sarawan Kaewmongkol  
*Veterinary World*, 15(3): 701-706

Research (Published online: 25-03-2022)

22. An assessment of knowledge and attitude toward antibiotic misuse by small-scale broiler farmers in Bogor, West Java, Indonesia  
Rusman Efendi, Etih Sudarnika, I. Wayan Teguh Wibawan and Trioso Purnawarman  
*Veterinary World*, 15(3): 707-713

Research (Published online: 25-03-2022)

23. Investigating antibiotic resistance in enterococci in Gabonese livestock  
Otsaghe Ekore Desire, Boundenga Larson, Onanga Richard, Mabika Mabika Rolande and Kumulungui Brice Serge  
*Veterinary World*, 15(3): 714-721

Research (Published online: 25-03-2022)

24. Effect of heat stress on vital and hematobiochemical parameters of healthy dogs  
Oyebisi Mistura Azeez, Folashade Helen Olaifa, Adakole Sylvanus Adah, Afisu Basiru, Ganiu Jimoh Akorede, Hauwa Moturayo Ambali, Kolawole Yusuf Suleiman, Fatima Sanusi and Mashood Bolaji  
*Veterinary World*, 15(3): 722-727

Research (Published online: 26-03-2022)

25. First study on phenotypic and morphological characteristics of Malaysian Kedah-Kelantan cattle (*Bos indicus*) and method of estimating their body weight  
Mohammed Sirajul Islam, Nurhusien Yimer, Abd Wahid Haron, Faez Firdaus Jesse Abdullah, Mark Hiew Wen Han, Kamalludin Mamat-Hamidi and Hafizah Binti Mohamad Zawawi  
*Veterinary World*, 15(3): 728-736

Research (Published online: 26-03-2022)

26. Comparison of two diagnostic methods through blood and urine sample analyses for the detection of ketosis in cattle  
Karla Verónica Borja, Andrés Miguel Amador, Silvana Hipatia Santander Parra, Cristian Fernando Cárdenas and Luis Fabian Núñez  
*Veterinary World*, 15(3): 737-742

Review (Published online: 28-03-2022)

27. Antimicrobial resistance: One Health approach  
Maria Elena Velazquez-Meza, Miguel Galarde-López, Berta Carrillo-Quiróz and Celia Mercedes Alpuche-Aranda  
*Veterinary World*, 15(3): 743-749

Research (Published online: 29-03-2022)

28. Comparative staining of *Rhinolophus* spp. white blood cells in blood smears  
Astghik Ghazaryan, Seda Adamyan, Tigran Hayrapetyan, George Papov, Lina Hakobyan, Liana Abroyan, Nane Bayramyan, Sona Hakobyan, Arpine Poghosyan, Hrag Torossian and Zaven Karalyan  
*Veterinary World*, 15(3): 750-756

Research (Published online: 29-03-2022)

29. Physicochemical properties, sensory characteristics, and antioxidant activity of the goat milk yogurt probiotic *Pediococcus acidilactici* BK01 on the addition of red ginger (*Zingiber officinale* var. *rubrum* rhizoma)  
Sri Melia, Indri Juliyarsi and Yulianti Fitri Kurnia  
*Veterinary World*, 15(3): 757-764

Research (Published online: 29-03-2022)

30. First study on diversity and antimicrobial-resistant profile of staphylococci in sports animals of Southern Thailand  
Punpichaya Fungwithaya, Kanpapat Boonchuay, Ruethai Narinthorn, Narin Sontigun, Chalutwan Sansamur, Yotsapat Petcharat, Thotsapol Thomrongsuwannakij and Tuempong Wongtawan  
*Veterinary World*, 15(3): 765-774

---

Research (Published online: 30-03-2022)

31. Polymorphism of leptin gene (single nucleotide polymorphisms c.73T>C) and its association with body weight and body measurements in Madura cattle

Kuswati Kuswati, Ahmad Furqon, Wike Andre Septian and Trinil Susilawati

Veterinary World, 15(3): 775-781

Research (Published online: 30-03-2022)

32. Association of pleomorphic adenoma gene 1 with body weight and measurement of Bali cattle (*Bos javanicus*)

Muhammad Cahyadi, Sukaryo Sukaryo, Mohammad Ilham Dhiaurridho, Thoriq Aldri Bramastya, Yuli Yanti, Joko Riyanto, Slamet Diah Volkandari and Pita Sudrajad

Veterinary World, 15(3): 782-788

Research (Published online: 31-03-2022)

33. Acute and sub-chronic oral toxicity study of purple sweet potato (*Ipomoea batatas* [L.] Lam) yogurt in mice (*Mus musculus*)

Astrid Feinisa Khairani, Yunisa Pamela, Nandina Oktavia, Achadiyahani Achadiyahani, M. Yusuf Adipraja, Prita Yasri Zhafira, Widad Aghnia Shalannandia and Nur Atik

Veterinary World, 15(3): 789-796

Research (Published online: 31-03-2022)

34. Impact of udder infections on biochemical composition of milk in context of pesticides exposure

Hala R. Ali, Samah F. Ali, Rania H. Abd-Algawad, Fayza A. Sdeek, Mahmoud Arafa, Essam Kamel and Momtaz A. Shahein

Veterinary World, 15(3): 797-808

Research (Published online: 31-03-2022)

35. A systematic review on urolithiasis in small ruminants according to nutrition-dependent prevalence and outcome after surgery

Marlene Sickinger and Anita Windhorst

Veterinary World, 15(3): 809-817

\*\*\*\*\*

## Experimental and natural infections of severe acute respiratory syndrome-related coronavirus 2 in pets and wild and farm animals

Gondo Mastutik<sup>1</sup>, Ali Rohman<sup>2</sup>, Reny I'tishom<sup>3</sup>, Ignacio Ruiz-Arrondo<sup>4</sup> and Ignacio de Blas<sup>5</sup>

1. Department of Anatomic Pathology, Faculty of Medicine, Universitas Airlangga, Surabaya 60131, Indonesia; 2. Department of Chemistry, Faculty of Science and Technology, Universitas Airlangga, Surabaya 60115, Indonesia; 3. Department of Medical Biology, Faculty of Medicine, Universitas Airlangga, Surabaya 60131, Indonesia; 4. Center for Rickettsioses and Arthropod-Borne Diseases, Hospital Universitario San Pedro-CIBIR, Logroño, Spain; 5. Department of Animal Pathology, Faculty of Veterinary Sciences, Instituto Universitario de Investigación Mixto Agroalimentario de Aragón (IA2), Universidad de Zaragoza, Spain.

**Corresponding author:** Gondo Mastutik, e-mail: [gondomastutik@fk.unair.ac.id](mailto:gondomastutik@fk.unair.ac.id)

**Co-authors:** AR: [alirohman@fst.unair.ac.id](mailto:alirohman@fst.unair.ac.id), RI: [ritishom@fk.unair.ac.id](mailto:ritishom@fk.unair.ac.id), IR: [irarrondo@riojasalud.es](mailto:irarrondo@riojasalud.es), IdB: [deblas@unizar.es](mailto:deblas@unizar.es)

**Received:** 19-10-2021, **Accepted:** 25-01-2022, **Published online:** 10-03-2022

**doi:** [www.doi.org/10.14202/vetworld.2022.565-589](http://www.doi.org/10.14202/vetworld.2022.565-589) **How to cite this article:** Mastutik G, Rohman A, I'tishom R, Ruiz-Arrondo I, de Blas I (2022) Experimental and natural infections of severe acute respiratory syndrome-related coronavirus 2 in pets and wild and farm animals, *Veterinary World*, 15(3): 565-589.

### Abstract

The severe acute respiratory syndrome-related coronavirus 2 (SARS-CoV-2) has spread globally and has led to extremely high mortality rates. In addition to infecting humans, this virus also has infected animals. Experimental studies and natural infections showed that dogs have a low susceptibility to SARS-CoV-2 infection, whereas domesticated cats and other animals in the family Felidae, such as lions, tigers, snow leopards, and cougars, have a high susceptibility to viral infections. In addition, wild white-tailed deer, gorillas, and otters have been found to be infected by SARS-CoV-2. Furry farm animals, such as minks, have a high susceptibility to SARS-CoV-2 infection. The virus appears to spread among minks and generate several new mutations, resulting in increased viral virulence. Furthermore, livestock animals, such as cattle, sheep, and pigs, were found to have low susceptibility to the virus, whereas chicken, ducks, turkeys, quail, and geese did not show susceptibility to SARS-CoV-2 infection. This knowledge can provide insights for the development of SARS-CoV-2 mitigation strategies in animals and humans. Therefore, this review focuses on experimental (both replication and transmission) *in vitro*, *ex vivo*, and *in vivo* studies of SARS-CoV-2 infections in pets and in wild and farm animals, and to provide details on the mechanism associated with natural infection.

**Keywords:** animal disease, coronavirus disease 2019, infectious disease, pandemic, severe acute respiratory syndrome-related coronavirus 2.

### Introduction

In December 2019, a new human infectious respiratory disease outbreak was documented in Wuhan, Hubei Province, China [1]. The disease spread rapidly through human transmission and became a global pandemic. The disease had a high health impact, amounting to 422,510,872 cases and 5894,569 deaths by February 19, 2022 [2]. The causative agent of the disease was identified as a new coronavirus strain [1]. As such, the disease was designated by the World Health Organization as the coronavirus disease 2019 (COVID-19), and the virus was named as the severe acute respiratory syndrome-related coronavirus 2 (SARS-CoV-2) by the International Committee on Taxonomy of Viruses [3]. The SARS-CoV-2 genome was 96.2% identical to the bat coronavirus RaTG13, *Rhinolophus affinis*, which was isolated at the Yunnan Province in China [4]. The increased genomic

similarity and close phylogenetic tree prove that bats were the origin of SARS-CoV-2 [4]. The intermediate host appeared to be the Malayan pangolin (*Manis javanica*), whose genome Pangolin CoV is 91% identical to that of the SARS-CoV-2 and is 90.55% identical to that of the BatCoV RaTG13 [5]. Snakes and turtles can be considered as intermediate hosts, but this is still controversial and requires further investigation [6]. SARS-CoV-2 was transmitted to humans in Wuhan, China [1], and spread worldwide. The first cases of SARS-CoV-2 infections were identified in Australia on January 19, 2020 [7], in Europe on January 24, 2020 [8], in the Americas on February 29, 2020 [9], and in the African continent on March 5, 2020 [10].

SARS-CoV-2 belongs to the subgenus *Sarbecovirus* (genus *Betacoronavirus*) in the family *Coronaviridae*. It is an enveloped virus with a single-stranded, positive-sense ribonucleic acid (RNA) genome with a nucleotide size of ~30 kb [1,11]. The SARS-CoV-2 genome encodes four structural proteins: The nucleocapsid protein (N), membrane protein (M), envelope protein (E), and surface spike protein (S) [1,11]. The S-protein of SARS-CoV-2 is a glycosylated transmembrane protein that forms a homotrimer structure. It protrudes from the viral surface and mediates viral entry into host cells [12]. The

Copyright: Mastutik, et al. Open Access. This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The Creative Commons Public Domain Dedication waiver (<http://creativecommons.org/publicdomain/zero/1.0/>) applies to the data made available in this article, unless otherwise stated.



S-protein of SARS-CoV-2 uses the angiotensin-converting enzyme 2 (ACE2) receptor as its binding receptor [13]. The sequence of the receptor-binding domain (RBD) of SARS-CoV-2, which includes the receptor-binding motif (RBM) of the S-protein, directly contacts the ACE2 receptor [13-15]. Human ACE2 is highly expressed in the lungs, heart, kidney, bladder, and gastrointestinal system [14,16]. ACE2 may also be present in mammalian cells. Analyses of the phylogenetic tree of animals that come into close contact with humans, such as pets and livestock, and ACE2 homology with the human ACE2 in various mammalian cells, showed a high degree of homology similarity [17-20]. *In silico* studies showed that ACE2 receptors from various domesticated animals, such as *Felis catus* (cat) and *Canis lupus familiaris* (dog), are highly homologous. *F. catus* and *C. lupus familiaris* have high degrees of similarities to human ACE2 of the orders of 85.2% and 83.4%, respectively [20]. Likewise, livestock, such as *Bos taurus* (cow), *Ovis aries* (sheep), and *Sus scrofa domestica* (pig), exhibit high similarity [17-20]. The interactions between the ACE2 amino acids of the cat, dog, cow, sheep, and pig and the RBD and RBM of the SARS-CoV-2 S-protein were predicted to allow the binding of SARS-CoV-2 [17,18]. Analyses of changes in the binding energy ( $\Delta\Delta G$ ) of the SARS-CoV-2 S-protein and the ACE2 complexes from cats, dogs, cows, sheep, and pigs showed that these animals belong to the risk category of SARS-CoV-2 infections, as indicated by  $\Delta\Delta G$  values  $\leq 3.72$  [21]. Consequently, these findings support the susceptibility of domesticated and livestock animals to SARS-CoV-2 infections.

In addition to infecting humans, SARS-CoV-2 has been reported to infect animals. Experimental infections of SARS-CoV-2 in animals have been reported in cats, dogs, ferrets, and poultry (March 2020) [22]. SARS-CoV-2 RNA has also been detected by the reverse transcription-polymerase chain reaction (RT-PCR) in pets from owners with confirmed COVID-19 infections. The first case was reported in dogs in Hong Kong (February 2020) [23], and in cats in Hong Kong (February-August 2020) [24], Belgium (March 2020) [25], and France (April 2020) [26]. The serological surveys found antibodies against SARS-CoV-2 in cats from Wuhan, China (during January-March 2020) [27] and in cats and dogs in Italy (May 2020) [28]. Furthermore, SARS-CoV-2 was detected in wild animals, such as lions, and tigers at the Bronx Zoo in New York City, United States of America (USA) in March 2020 [29,30]. Recently, antibodies to SARS-CoV-2 were also detected in wild white-tailed deer (*Odocoileus virginianus*) during January-March 2021 in four states in the USA [31]. SARS-CoV-2 RNA was detected in wastewater in Australia (published online on April 18, 2020) [32] and in the USA in January 2021 [33]. Both the SARS-CoV-2 RNA virus and antibodies against SARS-CoV-2 were also detected in farmed minks. The first case was also

detected in the Netherlands during April and May 2020 [34]. Furthermore, SARS-CoV-2 was reported to be transmitted from humans to minks, which led to the development of zoonotic diseases that have been proved to be transmitted back to humans [35]. Many animals, including those with experimentally induced or natural infections, are not yet known for their susceptibility to SARS-CoV-2 infections and many cases of natural infection have not been reported.

Therefore, this review focuses on experimental studies of SARS-CoV-2 infections, including *in vitro*, *ex vivo*, and *in vivo* studies on viral replication and transmission capabilities in pets and wild and farm animals. This explains the evidence of natural cases of SARS-CoV-2 infections in domesticated animals, including cats, dogs, minks, and wild animals, such as big cats and wild deer, in all continents until October 2021. This knowledge can be used to determine policy strategies adopted to mitigate the spread of infectious diseases in both animals and humans.

## SARS-CoV-2 Infections in Pets

### SARS-CoV-2 infections in cats

Some animals have been known to be experimentally infected with the SARS-CoV-2 virus. In addition, there has been evidence of natural infections in various animals from several countries, including China, which was the first country in which human infections were found, and in other countries in Asia, Europe, Australia, Africa, and the Americas. Some studies conducted to challenge animals against SARS-CoV-2 infection are presented in Table-1 [22,36-50], whereas natural infections in animals, including domestic animals, farm animals, and wild animals, are listed in Table-2 [23-29,31,34,35,51-66], and natural infections in the USA are listed in Table-3 [67-90]. Experimental infections and natural cases with the presumed sources of infection and their transmission are summarized in Figure-1 [4,5,23-29,31,34,35,40,41,43-66,91].

Experimental studies on SARS-CoV-2 replication and transmission have been observed in cats [22,36-39]. The viral replication was investigated in juvenile [22], sub-adult [22,36,38,39], and adult cats [37]. In juvenile cats, SARS-CoV-2 was efficiently replicated in the upper and lower respiratory tracts [22]. In young cats, viral RNA was replicated and detected in nasal or oropharyngeal swabs during the 1<sup>st</sup> week post-infection and peak viral shedding at 4-5 days post-infection [36,38,39]. In sub-adult cats, the virus replicated efficiently in the upper respiratory tract in the beginning of infection, but some replicated in the lower respiratory tract and in the small intestine [22]. Viral replication and shed viruses were also found orally and nasally up to days 5 post-infection in adult cats [37].

All young and sub-adult cats did not show clinical signs and symptoms of the disease [36,38,39]. However, the histopathological features of the respiratory tract showed lymphocytic inflammation

**Table-1:** Experimental SARS-CoV-2 infection in animals.

Species	Method	Age	Route and Dose	Virus Isolation	Clinical Sign	Replication virus	Antibody to SARS-CoV-2	Transmission	Susceptibility	Reference
Cat ( <i>Felis catus</i> )	<i>In vivo</i>	70-100 days	Intranasal with 10 <sup>5</sup> PFU of CTan-H	SARS-CoV-2/CTan/human/2020/Wuhan (CTan-H)	N/A	Yes, and shed virus	Yes	Yes	High	[22]
	<i>In vivo</i>	5-18-week-old	Intranasal, oral, intratracheal, ocular by 5.2×10 <sup>5</sup> PFU	UT-NCGM02/Human/2020/Tokyo	No	Yes, and shed virus	Yes	Yes	High	[36]
	<i>In vivo</i>	6-9 months	Intranasal with 10 <sup>5</sup> PFU of CTan-H	SARS-CoV-2/CTan/human/2020/Wuhan (CTan-H)	N/A	Yes, and shed virus	Yes	Yes	High	[22]
	<i>In vivo</i>	5-8 years	Nares (500 µL/nare) for a total volume of 1 mL (3.0×10 <sup>5</sup> PFU)	SARS-CoV-2 virus strainWA1/2020WY96	No	Yes, and shed virus	Yes	Yes	High	[37]
	<i>In vivo</i>	15-18-week-old	Intranasal, oral, intratracheal, ocular by 5.2×10 <sup>5</sup> PFU	UT-NCGM02/Human/2020/Tokyo	No	Yes, and shed virus	Yes	Yes	High	[38]
	<i>In vivo</i>	4.5-5 months	Intranasal and oral with 1×10 <sup>6</sup> TCID <sub>50</sub> /mL	SARS-CoV-2 USA-WA1/2020 strain	No	Yes, and shed virus	Yes	Yes	High	[39]
Dog ( <i>Canis lupus</i> )	<i>In vivo</i>	3 months	Intranasal with 10 <sup>5</sup> PFU of CTan-H	SARS-CoV-2/CTan/human/2020/Wuhan (CTan-H)	N/A	Yes, but not shed virus	Yes	No	Low	[22]
	<i>In vivo</i>	5-6 years	Nares (500 µL/nare) for a total volume of 1 mL (1.4×10 <sup>5</sup> PFU)	SARS-CoV-2 virus strainWA1/2020WY96	No	Yes, but not shed virus	Yes	N/A	Low	[37]
Cattle ( <i>Bos taurus</i> )	<i>In vitro</i> : bovine turbinatae, <i>Bos taurus</i> trachea normal (EBTr (NBL-4)), cow pulmonary artery epithelial, primary fetal bovine lung, and fetal bovine kidney cells	N/A	Multiplicity of infection of 1 or 0.1 (MOI=1 or 0.1)	SARSCoV-2 isolate TGR/NY/20	N/A	Not replicate	N/A	N/A	N/A	[40]

(Contd...)

Table-1: (Continued).

Species	Method	Age	Route and Dose	Virus Isolation	Clinical Sign	Replication virus	Antibody to SARS-CoV-2	Transmission	Susceptibility	Reference
Cattle ( <i>Bos taurus</i> )	<i>Ex vivo</i> : Respiratory ex vivo organ cultures <i>In vivo</i>	18 months  6 weeks	Infected with $10^3$ TCID <sub>50</sub> /mL  Intratracheal or intravenous, 5 mL each respective route	SARS-CoV-2/ INM11-Isolate/2020/ Italy (D614); SARS-CoV-2/ IZSAM/46419 (D614G) SARSCoV-2 isolate TGR/NY/20	N/A  High temp and mild caught	Yes  Yes, but not shed virus	N/A  Yes	N/A  N/A	N/A  Low	[41]  [40]
	<i>In vivo</i>	<1 year	Intranasal with $1 \times 10^5$ 50% tissue culture infectious dose of SARS-CoV-2	SARS-CoV-2 Strain 2019_nCoV Muc-1MB-1	N/A	Yes, but not shed virus	Yes	No	Low	[42]
Sheep ( <i>Ovis aries</i> )	<i>Ex vivo</i> : Respiratory ex vivo organ cultures	10 months	Infected with $10^3$ TCID <sub>50</sub> /mL	SARS-CoV-2/ INM11-Isolate/2020/ Italy (D614); SARS-CoV-2/ IZSAM/46419 (D614G)	N/A	Yes	N/A	N/A	Low	[41]
White tail deer ( <i>Odocoileus virginianus</i> )	<i>In vitro</i> : Deer lung cells <i>In vitro</i> : lung cells isolated from white-tailed deer, mule deer and elk	N/A  N/A	Inoculated multiplicities of infection of 0.1 and 1  Infected at approximately 0.1 MOI	SARS-CoV-2 isolate TGR/NY/20  SARS-CoV-2 lineage A WA1 strain	N/A  N/A	Yes  Yes, in white-tailed deer, mule deer lung cells	N/A  N/A	N/A  N/A	N/A  N/A	[43]  [44]
	<i>In vivo</i>	6 weeks	Intranasal with 5 mL (2.5 mL per nostril) of a virus suspension containing $10^{6.3}$ TCID <sub>50</sub> /mL	SARS-CoV-2 isolate TGR/NY/20	Subclinical viral infection	Yes, and shed virus	Yes	Yes	High	[43]
	<i>In vivo</i>	2 years	Intranasal and oral with 2 mL dose of $1 \times 10^6$ TCID <sub>50</sub> per animal	1:1 titer ratio of lineage A WA1 and the alpha VOC B.1.1.7 strain	Subclinical viral infection	Yes, and shed virus	Yes	Yes, and vertical	High	[44]

(Contd...)

Table-1: (Continued).

Species	Method	Age	Route and Dose	Virus Isolation	Clinical Sign	Replication virus	Antibody to SARS-CoV-2	Transmission	Susceptibility	Reference
Pig ( <i>Sus scrofa domestica</i> )	<i>In vitro</i> : Porcine kidney-15, swine kidney -6, and swine testicle <i>In vitro</i> : ST and PK-15 cell lines	N/A	Inoculated with 10 <sup>5</sup> TCID <sub>50</sub> SARS-CoV-2	SARS-CoV-2 2019_nCoV Muc-IMB-1	N/A	Yes, in SK-6 and ST	N/A	N/A	N/A	[45]
		N/A	0.05 MOI of passage 3 of the VeroE6-passaged SARS-CoV-2	SARS-CoV-2 USA-WA1/2020 isolate	N/A	Yes, in ST and PK-15	N/A	N/A	N/A	[46]
	<i>Ex vivo</i> : Respiratory ex vivo organ cultures	12 months	Infected with 10 <sup>3</sup> TCID <sub>50</sub> /mL	SARS-CoV-2/INM11-Isolate/2020/Italy (D614G); SARS-CoV-2/IZSAM/46419 (D614G)	N/A	Not detected	N/A	N/A	N/A	[41]
	<i>In vivo</i>	5 weeks	Oral, intranasal, intratracheal with 1 × 10 <sup>6</sup> TCID <sub>50</sub> of SARS-CoV-2	SARS-CoV-2 USA-WA1/2020 isolate	No	Not detected	Not detected	No	No	[46]
	<i>In vivo</i>	N/A	Intranasal with 10 <sup>5</sup> PFU of CTan-H	SARS-CoV-2/CTan/human/2020/Wuhan (CTan-H)	N/A	Not detected	Not detected	No	No	[22]
	<i>In vivo</i>	9 weeks	Intranasal with 10 <sup>5</sup> TCID <sub>50</sub> SARS-CoV-2	SARS-CoV-2 2019_nCoV Muc-IMB-1	No	Not detected	Not detected	N/A	No	[45]
	<i>In vivo</i>	5-6 weeks	Intranasal, intratracheal, intramuscular and intravenous 10 <sup>5.8</sup> TCID <sub>50</sub>	SARS-CoV-2 isolate (GISAID ID EPI_ISL_510689)	No	Yes, but not shed virus	Yes, at IM, IV route	N/A	No	[47]
	<i>In vivo</i>	8 weeks	Intranasal and pharynx routes of 10 <sup>6</sup> PFU/animal	SARS-CoV-2 isolate hCoV-19/Canada/ON-VIDO-01/2020	No, but an animal yes)	Yes, but not shed virus	No	No	Low	[48]
	<i>In vivo</i>	3 weeks	Intravenous, intratracheal, and intranasal 6.8 × 10 <sup>6</sup> TCID <sub>50</sub> /mL	SARS-CoV-2 isolate used in our study (TGRI/NY/20)	No	Yes, but not shed virus	Yes, but not sustained	No	Low	[49]

(Contd...)

Table-1: (Continued).

Species	Method	Age	Route and Dose	Virus Isolation	Clinical Sign	Replication virus	Antibody to SARS-CoV-2	Transmission	Susceptibility	Reference
Chickens ( <i>Gallus gallus domesticus</i> )	<i>In vivo</i> : Embryonating chicken eggs	N/A	Yolk sac, chorioallantoic sac, and chorioallantoic membrane	USA-WA1/2020 isolate of SARS-CoV-2 (BEI NR-58221)	N/A	Not detected	Not detected	N/A	No	[50]
	<i>In vivo</i> : ECE	N/A	Inoculated SARS-CoV-2 in ECE	SARS-CoV-2 2019_nCoV Muc-IMB-1	N/A	Not detected	N/A	N/A	No	[45]
	<i>In vivo</i>	5 weeks	Intranasal with 10 <sup>5</sup> TCID <sub>50</sub> SARS-CoV-2	SARS-CoV-2 2019_nCoV Muc-IMB-1	No	Not detected	Not detected	N/A	No	[45]
	<i>In vivo</i>	N/A	Challenged with SARS-CoV-2	USA-WA1/2020 isolate of SARS-CoV-2 (BEI NR-58221)	No	Not detected	Not detected	N/A	No	[50]
	<i>In vivo</i>	N/A	Intranasal with 10 <sup>5</sup> PFU of CTan-H	SARS-CoV-2/CTan/human/2020/Wuhan (CTan-H)	N/A	Not detected	Not detected	No	No	[22]
Turkeys ( <i>Meleagris gallopavo</i> )	<i>In vivo</i>	N/A	Challenged with SARS-CoV-2	USA-WA1/2020 isolate of SARS-CoV-2 (BEI NR-58221)	No	Not detected	Not detected	N/A	No	[50]
Ducks ( <i>Anas platyrhynchos domesticus</i> )	<i>In vivo</i>	N/A	Intranasal with 10 <sup>5</sup> PFU of CTan-H	SARS-CoV-2/CTan/human/2020/Wuhan (CTan-H)	N/A	Not detected	Not detected	No	No	[22]
	<i>In vivo</i>	N/A	Challenged with SARS-CoV-2	USA-WA1/2020 isolate of SARS-CoV-2 (BEI NR-58221)	No	Not detected	Not detected	N/A	No	[50]
Quail ( <i>Coturnix japonica</i> )	<i>In vivo</i>	N/A	Challenged with SARS-CoV-2	SARS-CoV-2 (BEI NR-58221)	No	Not detected	Not detected	N/A	No	[50]
Geese ( <i>Anser cygnoides</i> )	<i>In vivo</i>	N/A	Challenged with SARS-CoV-2	USA-WA1/2020 isolate of SARS-CoV-2 (BEI NR-58221)	No	Not detected	Not detected	N/A	No	[50]

PFU=Plaque-forming units, SARS-CoV-2=Severe acute respiratory syndrome-related coronavirus 2, N/A=Not available

**Table-2:** Natural infections of SARS-CoV-2 in pet, wild and farm animals.

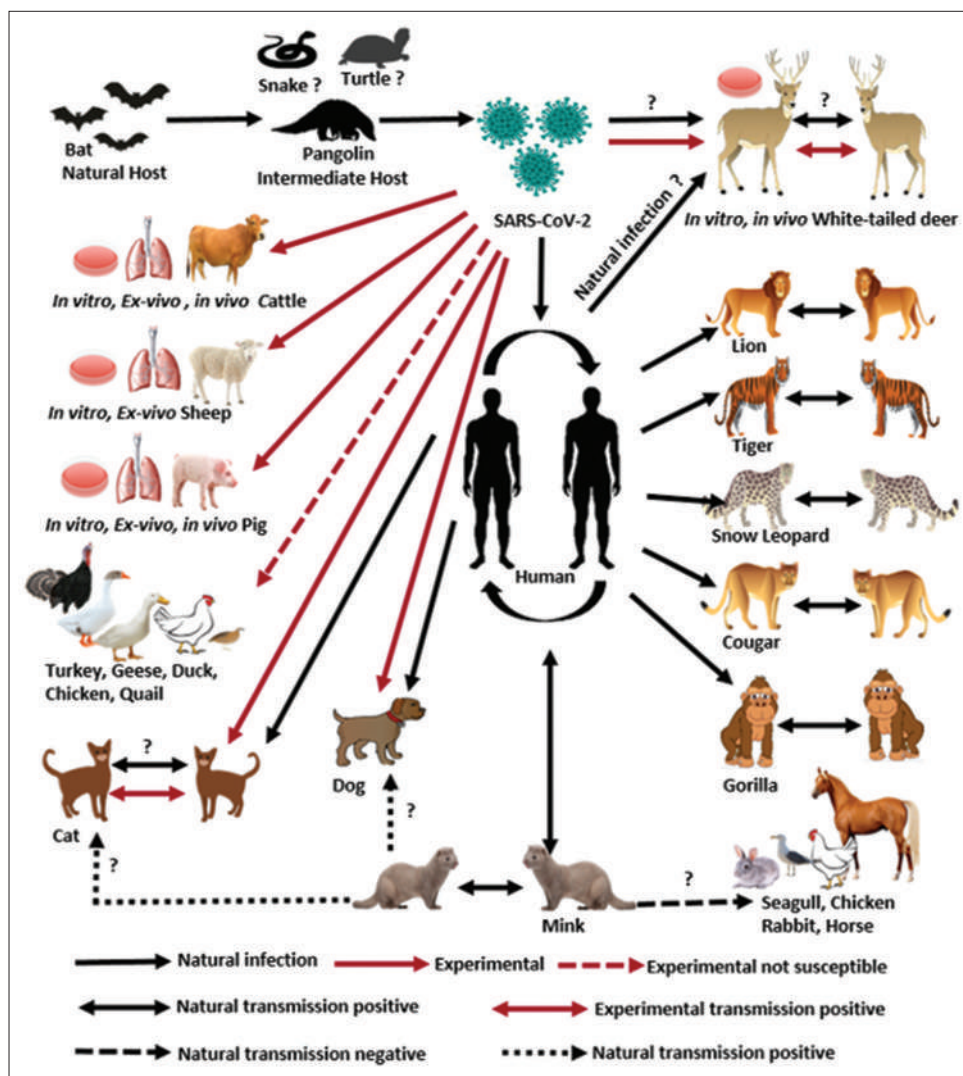
Species	Location	Sample Sources	Total sample	Total Positive	Clinical Sign	RNA Virus Detected	Antibody to SARS-CoV-2	Reference
Cat ( <i>Felis catus</i> )	Wuhan (China)	Animal shelters, pet hospital, and Households confirmed COVID-19	102	15	N/A	Negative	Positive	[27]
	Hong Kong (China)	Households confirmed COVID-19	7	0	Asymptomatic	Negative	Negative	[23]
	Hong Kong (China)	Households confirmed COVID-19	50	6	Asymptomatic	Positive	Positive	[24]
	Spain	Households confirmed COVID-19	8	1	Asymptomatic	Positive	N/A	[52]
	Spain	Households confirmed COVID-19	1	1	Feline hypertrophic cardiomyopathy, but the animal was also infected by SARS-CoV-2	Positive	Positive	[53]
	Belgium	Households confirmed COVID-19	1	1	Mild gastrointestinal and respiratory signs	Positive	Positive	[25]
	France	Households confirmed COVID-19	22	1	Mild respiratory and digestive signs.	Positive	Positive	[26]
	Italy	Households confirmed COVID-19 or living in geographic areas that were severely affected by COVID-19	191	11	Not clearly explained	Negative	Positive	[28]
	Rio de Janeiro (Brazil)	Households confirmed or not confirmed COVID-19 and stray animals	49	1	N/A	Negative	Positive	[54]
	Rio de Janeiro (Brazil)	Households confirmed COVID-19	10	4	Unspecified, mild, reversible signs, respiratory or gastrointestinal signs	Positive	Positive	[55]
Tiger ( <i>Panthera tigris</i> )	New York (USA)	Households confirmed COVID-19	2	2	Sneezing, clear ocular discharge, and mild lethargy	Positive	N/A	[51]
	New York (USA)	Bronx Zoo	5	4	Mild respiratory signs	Positive	N/A	[29]
Lion ( <i>Panthera leo</i> )	Jakarta (Indonesia)	Ragunan Jakarta Zoo	2	2	Mild respiratory signs and general symptoms	Positive	N/A	[65,66]
	New York (USA)	Bronx Zoo	3	3	Mild respiratory signs	Positive	N/A	[29]
	Catalonia (Spain)	Barcelona Zoo	12	3	Mild respiratory signs	Positive	Positive	[64]
	Tamil Nadu (India)	Arignar Anna Zoological Park in Chennai	11	9	Mild respiratory signs and general symptoms	Positive	N/A	[62]

(Contd...)

**Table-2:** (Continued)

Species	Location	Sample Sources	Total sample	Total Positive	Clinical Sign	RNA Virus Detected	Antibody to SARS-CoV-2	Reference
	Uttar Pradesh and Rajasthan (India)	Lion Safari Park, Etawah and Nahargarh Biological Park	3	12	Mild respiratory signs and general symptoms	Positive	Positive	[63]
Snow leopard ( <i>Panthera uncia</i> )	Louisville (USA)	Louisville Zoo	3	3	Mild respiratory signs	Positive	N/A	[61]
Cougar ( <i>Puma concolor</i> )	San Diego (USA)	San Diego Zoo	1	1	N/A	Positive	N/A	[60]
Dog ( <i>Canis lupus familiaris</i> )	Texas (USA)	Texas animals	1	1	Mild respiratory signs	Positive	N/A	[59]
	Hong Kong (China)	Quarantine animal from households with confirmed COVID-19	15	2	Asymptomatic	Positive	Positive	[23]
	Spain	Households confirmed COVID-19	12	0	Asymptomatic	Negative	N/A	[52]
	France	Households confirmed COVID-19	11	0	Mild respiratory and digestive signs	Negative	Negative	[26]
	Italy	Households confirmed COVID-19 or living in geographic areas that were severely affected by COVID-19	451	15	Not clearly explained	Negative	Positive	[28]
	Rio de Janeiro (Brazil)	Households confirmed or not confirmed COVID-19 and stray animals	47	1	N/A	Negative	Positive	[54]
	Rio de Janeiro (Brazil)	Households confirmed COVID-19	29	9	Unspecified, mild, reversible signs, respiratory or gastrointestinal signs	Positive	Positive	[55]
White tail deer ( <i>Odocoileus virginianus</i> )	Michigan, Pennsylvania, Illinois, New York (USA)	Wild white-tailed deer population	385	152	N/A	N/A	Positive	[31]
Mink ( <i>Neovison vison</i> )	The Netherlands	Mink farms	16 mink farms	N/A	Mild to severe respiratory distress	Positive	N/A	[34,35,56]
	Denmark	Mink farms	1147 mink farms	290 mink farms	N/A	Positive	N/A	[57]
	Poland	Mink farms	28 mink farms	1 mink farm	N/A	Positive (70% sample)	Positive (30% sample)	[58]
Guinea pig ( <i>Cavia porcellus</i> )	Spain	Households confirmed COVID-19	1	1	Asymptomatic	Negative	N/A	[52]
Rabbit ( <i>Oryctolagus cuniculus</i> )	Spain	Households confirmed COVID-19	1	2	Asymptomatic	Negative	N/A	[52]

SARS-CoV-2=Severe acute respiratory syndrome-related coronavirus 2, N/A=Not available



**Figure-1:** Experimental and natural infections of the severe acute respiratory syndrome-related coronavirus 2 (SARS-CoV-2) in pets and wild and farm animals [4,5,23-29,31,34,35,40,41,43-66,91]. SARS-CoV-2 was assumed to originate in the bat species [4], and the virus was then transmitted from them to humans through an intermediate animal host, that is, pangolins [5]. Indeed, the spread of this virus among humans and many animals has been reported widely. These animals include domestic cats [23-28,51-55], dogs [23,26,28,52,54,55], and wild Felidae families, such as tigers [29,65,66], lions [29,62-64], snow leopards [60,61] and cougars [59], as well as gorilla [91]. It was confirmed that the animals acquired viral infection from humans infected with SARS-CoV-2. The virus spread among these group animals in the same cage. Another wild animal susceptible to SARS-CoV-2 infection is the white-tailed deer [31]. Experimentally [43,44], SARS-CoV-2 has been shown to replicate *in vitro* and transmit *in vivo* among these animals and vertically to the fetus. In natural infections, white-tailed deer were found positive for the SARS-CoV-2 infection and had high seroprevalence [31], although the source of transmission from human or nature is still unclear. Minks were naturally infected with SARS-CoV-2 from humans, and subsequently spread the virus among them, and the virus was transmitted back to humans [34,35,56-58]. It is not clear whether minks can transmit the virus to other animals, such as dogs, cats, seagulls, chickens, horses, and rabbits in farms. Experimentally, SARS-CoV-2 cannot infect poultries, such as chickens, ducks, geese, turkeys, and quails [45,50]. The virus was reported to infect several livestock animals experimentally, including cattle [40,41], sheep [41], and pigs [22,41,45-49], but natural infections have not been reported.

during early infection in combination with mixed inflammation during the peak infection period and decreased during the recovery period [38]. Moderate lesions were found in the lungs in the early infection stage [38,39] but tended to persist during the clearance of the virus, during which the lesions progressed to chronic histopathological features [38]. Adult cats exhibited no clinical signs of diseases, but histopathological features indicated subclinical pathological changes in the upper respiratory tract [37]. Juvenile cats exhibited massive lesions in the upper and lower respiratory tracts, suggesting that young cats are more

susceptible to SARS-CoV-2 infections than adult cats [22]. Viral RNA obtained from nasal swabs was not detectable in re-infected animals. Microscopically, the lungs appeared with peribronchial fibrosis and thickening of the alveolar septa [38]. All these experiments revealed that cats were highly susceptible to SARS-CoV-2 infection. The virus can replicate efficiently in the respiratory tract and then shed nasally and orally, even though the cats did not exhibit any clinical symptoms [22,36-39].

The transmission of SARS-CoV-2 from inoculated cats to naive-contact cats was observed in



**Table-3:** Natural infection of severe acute respiratory syndrome-related coronavirus 2 in USA reported by OIE.

Species	No. of follow-up report	Location	Date of outbreak	Suspect	Case	Death	Clinical signs	Reference
Domestic cat ( <i>Felis catus</i> )	No. 2 and 3	Nassau County, Nassau, New York,	April 1, 2020	1	1	-	Respiratory signs	[67,68]
	No. 2 and 3	Orange County, Orange, New York	April 6, 2020	2	1	-	Respiratory signs	[67,68]
	No. 5	Carver County, Carver, Minnesota	May 20, 2020	1	1	-	Respiratory signs	[75]
	No. 6 and 7	Cook County, Cook, Illinois	May 19, 2020	1	1	-	Respiratory signs	[76,77]
	No. 9	Orange County, Orange, California	June 26, 2020	1	1	1	Respiratory and cardiac signs	[78]
	No. 9	Orange County, Orange, California	June 27, 2020	1	1	-	Asymptomatic	[78]
	No. 11	Brazos County, Brazos, Texas	June 28, 2020	1	1	-	Asymptomatic	[79]
	No. 11	Maricopa County, Maricopa, Arizona	July 10, 2020	1	-	-	N/A	[79]
	No. 12	Brazos County, Brazos, Texas	July 17, 2020	1	1	-	Asymptomatic	[80]
	No. 14	Brazos County, Brazos, Texas	July 29, 2020	3	1	-	Asymptomatic	[81]
	No. 16	Coweta County, Coweta, Georgia	July 14, 2020	1	1	-	Respiratory signs	[82]
	No. 16	Hartford County, Hartford, Maryland	August 10, 2020	5	1	-	Respiratory signs	[82]
	No. 16	Contra Costa County, Contra Costa, California	August 13, 2020	1	1	-	Respiratory signs	[82]
	No. 17	Rapides Parish, Rapides, Louisiana	August 17, 2020	4	1	-	Respiratory signs	[69]
	No. 18	Brazos County, Brazos, Texas	August 11, 2020	1	1	-	Asymptomatic	[70]
	No. 18	Somervell County, Somervell, Texas	August 12, 2020	9	1	-	Asymptomatic	[70]
	No. 18	Brazos County, Brazos, Texas	August 21, 2020	1	1	-	Asymptomatic	[70]
	No. 19	Fayette County, Fayette, Kentucky	September 6, 2020	3	1	-	Respiratory signs	[71]

(Contd...)

**Table-3:** (Continued)

Species	No. of follow-up report	Location	Date of outbreak	Suspect	Case	Death	Clinical signs	Reference
	No. 20	Brazos County, Brazos, Texas	September 11, 2020	1	1	-	Asymptomatic	[72]
	No. 21	Lee County, Lee, Alabama	September 25, 2020	4	2	1	Respiratory signs	[73]
	No. 23	Cumberland County, Cumberland, Pennsylvania	October 02, 2020	1	1	-	Respiratory signs	[74]
Total of Domestic cat ( <i>Felis catus</i> )				44	21	2		
Domestic dogs ( <i>Canis lupus familiaris</i> )	No. 4	Richmond County, Richmond, New York	April 15, 2020	2	1	-	Respiratory signs	[86]
	No. 8	Berrien County, Berrien, Georgia	June 22, 2020	3	1	-	Neurological signs	[83]
	No. 9	Orange County, Orange, California	June 28, 2020	1	1	-	Asymptomatic	[78]
	No. 10	Charleston County, Charleston, South Carolina	June 26, 2020	3	1	-	Respiratory signs	[84]
	No. 11	Brazos County, Brazos, Texas	June 28, 2020	2	-	-	Asymptomatic	[79]
	No. 11	Maricopa County, Maricopa, Arizona	July 10, 2020	3	1	-	Respiratory signs	[79]
	No. 12	Brazos County, Brazos, Texas	July 17, 2020	2	-	-	N/A	[80]
	No. 13	Livingston Parish, Livingston, Louisiana	July 22, 2020	2	1	-	N/A	[85]
	No. 14	Brazos County, Brazos, Texas	July 28, 2020	1	1	-	Asymptomatic	[81]
	No. 14	Moore County, Moore, North Carolina	August 4, 2020	2	1	1	Respiratory signs and cardiac arrest	[81]
	No. 16	Hartford County, Hartford, Maryland	August 10, 2020	1	-	-	N/A	[82]
	No. 17	Rapides Parish, Rapides, Louisiana	August 17, 2020	1	-	-	N/A	[69]
	No. 18	Brazos County, Brazos, Texas	August 11, 2020	1	1	-	Respiratory signs	[70]
	No. 18	Brazos County, Brazos, Texas	August 12, 2020	2	1	-	Respiratory signs	[70]
	No. 18	Somervell County, Somervell, Texas	August 12, 2020	2	-	-	Asymptomatic	[70]

(Contd...)

**Table-3:** (Continued)

Species	No. of follow-up report	Location	Date of outbreak	Suspect	Case	Death	Clinical signs	Reference
	No. 18	Brazos County, Brazos, Texas	August 21, 2020	1	-	-	N/A	[70]
	No. 18	Brazos County, Brazos, Texas	August 21, 2020	1	1	-	Asymptomatic	[70]
	No. 20	Brazos County, Brazos, Texas	September 14, 2020	1	1	-	Respiratory signs	[72]
	No. 23	Brazos County, Brazos, Texas	October 01, 2020	2	1	-	Respiratory signs	[74]
Total of Domestic dogs ( <i>Canis lupus familiaris</i> )				33	13	1		
Domestic American Mink ( <i>Neovison vison</i> )	No. 15	Utah, Utah	June 26, 2020	20,000	N/A	3,524	Respiratory signs and death	[87]
	No. 15	Utah, Utah	August 2, 2020	8,983	N/A	1,451	Respiratory signs and death	[87]
	No. 16	Utah, Utah	August 03, 2020	6,326	N/A	1,554	Respiratory signs and death	[82]
	No. 16	Utah, Utah	August 05, 2020	3,643	N/A	1,119	Respiratory signs and death	[82]
	No. 16	Utah, Utah	August 05, 2020	1,705	N/A	205	Respiratory signs and death	[82]
	No. 19	Utah, Utah	September 08, 2020	1,500	N/A	59	Respiratory signs and death	[71]
	No. 20	Utah, Utah	September 07, 2020	600	N/A	146	Respiratory signs and death	[72]
	No. 20	Utah, Utah	September 20, 2020	14,000	N/A	247	Respiratory signs and death	[72]
	No. 21	Michigan, Michigan	September 27, 2020	17,000	N/A	2,000	Respiratory signs and death	[73]
	No. 21	Wisconsin, Wisconsin	September 30, 2020	14,600	N/A	1,800	Respiratoandry signs and death	[73]
	No. 22	Utah, Utah	September 29, 2020	300	N/A	126	Respiratory signs and death	[88]
	No. 25	Utah, Utah	October 08, 2020	3,000	N/A	373	Respiratory signs and death	[89]
	No. 25	Wisconsin, Wisconsin	October 19, 2020	22,500	N/A	2,200	Respiratory signs and death	[89]
	No. 25	Utah, Utah	October 22, 2020	13,200	N/A	585	Respiratory signs and death	[89]
	No. 25	Utah, Utah	October 25, 2020	38,000	N/A	739	Respiratory signs and death	[89]
	No. 26	Oregon, Oregon	October 22, 2020	12,000	N/A	2	Respiratory signs and death	[90]
Total of Domestic American Mink ( <i>Neovison vison</i> )				177,357		16,130		

N/A=Not available

juvenile, sub-adult, and adult cats [22,36-39]. In naive co-housed cats, viral RNA was detected in rectal swabs and in the upper respiratory tract tissues at days 1-3 post-exposure, persisted at days 5-9

post-exposure, and the shed virus reached the peak at days 4-5 post-exposure [22,36,37,39]. Viral RNA in the naive co-housed cats was detected in the upper respiratory tract and esophagus but not in the lung or other organs on day 5 post-exposure [37]. The virus was optimally replicated and longer in the upper respiratory tract [36-39] than in the lower respiratory tract [39]. Subsequently, the virus was excreted and spread from the oral or nasal cavity [36,37,39] with respiratory droplets to the naive co-housed cats through the airborne route [22]. This suggested that cats allowed viral replication and the virus were then transmitted by direct contact (co-housed) to naive cats. It is proved the transmission of SARS-CoV-2 from infected cats to other cats [22,37,39].

In addition, re-challenges of SARS-CoV-2 infections in cats were observed at 21 days [39] and 28 days after the first infection [38]. A re-challenge at 21 days showed that the animals were asymptomatic, but viral RNA was found high in the upper respiratory tract and gastrointestinal tissue, and low in the lower respiratory tract, lymphatic tissues, heart, and olfactory bulb [39]. On the contrary, re-infection at 28 days showed no viral RNA detection in nasal, oral, and rectal swabs or in the respiratory tract, brain, liver, spleen, kidney, small and large intestines, heart, and eyelid tissues on day 3 after re-infection [38]. This may be related to the immunity to SARS-CoV-2. Immunoglobulin M bound to the RBD of SARS-CoV-2 was detected on day 7 and reached the peak on day 14, and decreased up to day 28, whereas immunoglobulin G was detected on day 7 post-infection and continued to increase up to day 28; it then reached a plateau on day 42 post-infection [37]. Immunity on day 28 after the first infection may have reached its peak to provide the protective effect on the second challenge infection [37].

In addition to the proof on experimentally induced SARS-CoV-2 infections, some studies reported natural infections in several animals, as summarized in Table-2. In Hong Kong, the natural infection with SARS-CoV-2 has been observed in 6 of 50 (12%) quarantined animals from households or animals with close contact with patients with COVID-19 [24]. A serological study in cats collected from animal shelters, pet hospitals, and households with COVID-19 in Wuhan, China, from January to March 2020 showed that 15 of 102 (14.7%) cats were positive for antibodies against SARS-CoV-2. However, all nasopharyngeal and anal swabs were negative for SARS-CoV-2 viral RNA [27]. In Thailand, a serological survey was conducted on cats from April to December 2020 and showed that 4 of 1112 sera antibodies were positive to antibodies against SARS-CoV-2 [92].

Natural SARS-CoV-2 infection was reported in Europe, including Belgium, Spain, France, and Italy. In Belgium, a cat from the owner with COVID-19 in March 2020 was positive for the SARS-COV-2 viral RNA and developed neutralizing antibodies against

SARS-CoV-2 [25]. In La Rioja, Northern Spain, a study on 23 asymptomatic animals in quarantine from April 8 to May 4, 2020, including eight cats from an owner with COVID-19, found that one of eight cats was positive for SARS-CoV-2 viral RNA based on RT-PCR [52]. Two cats of the owners who died from COVID-19 on March 18, 2020, in Spain, was reported seroconverted to SARS-CoV-2; however, viral RNA was detected in the first cat but not in the second cat [53]. In France, a cohort study conducted on 22 cats from owners who were infected, or suspected to be infected, showed that a cat was positive for viral RNA and antibodies. This cat had mild respiratory and digestive signs. Furthermore, the genomic analysis of SARS-CoV-2 from this cat revealed a genome resembling the SARS-CoV-2 genome in most French humans [26]. In addition, another study in France reported that seroprevalent antibodies against SARS-CoV-2 were increased in cats and dogs from the confirmed COVID-19 household cases by 21.3% and by 2.6% in no confirmed COVID-19 households [93]. In Italy, an epidemiological study involving 277 cats living in SARS-CoV-2-positive households or in the geographic areas severely affected by COVID-19 found that several animals developed neutralizing antibodies. In contrast, viral RNA was negative in all swab samples [28].

SARS-CoV-2 infections in cats were reported in Rio de Janeiro, Brazil. Data were collected from June to August 2020 from cats living in a household with owners with confirmed COVID-19 and stray animals. Interestingly, serum from a stray cat tested positive for antibodies to SARS-CoV-2, even though the tests were negative for viral RNA [54]. Another study in the same city showed that cats from households with owners positive for COVID-19 showed positive results for viral RNA (3 of 10 household cats) and developed a neutralizing antibody to SARS-CoV-2 (two of four cats) [55].

The first infection with SARS-CoV-2 in cats in the USA was reported in April 2020 [67,68]. The other cases were reported by the World Organization for Animal Health (OIE) in the follow-up reports, with numbers of 2, 3, 5, 6, 7, 9, 11, 12, 14, 16, 17, 18, 19, 20, 21, and 23 [67-82], as listed in Table-3. SARS-CoV-2 infections were confirmed by RT-PCR in a total of 44 suspected cats and 21 cats [67-82]. In the first case, two cats had clinical signs of respiratory illness from owners with COVID-19. Both cats were positive for SARS-CoV-2 RNA and developed antibodies against SARS-CoV-2 [51,67]. Recently, in Texas, USA, infection with SARS-CoV-2 was reported in cats of the COVID-19 household, which showed 17.6% of the cats were positive for SARS-CoV-2, and 43.8% of the cats were found to have neutralizing antibodies against SARS-CoV-2 [94].

The susceptibility of animals to SARS-CoV-2 infection was predicted by comparing ACE2 of animals and humans [17,18,95]. ACE2 is the receptor

that interacts with the spike protein of SARS-CoV-2 that allows viral entry to host cells [17,18,95]. Cats ACE2 presented four amino acid changes related to Gln24Leu, Asp30Glu, Asp38Glu, and Met82Thr [95]. The residue Asp30 in ACE2 was negatively charged and formed a salt bridge with Lys417 (positively charged) in the S-protein of SARS-CoV-2. This stable bridge is located in the middle of the surface interaction [95]. The Asp30 to Glu mutation residue formed more stable bridges than Asp30 residue [95]. His34, located in the center of surface interaction, and the N-glycosylation site at residue Asn90 were similar to those of human ACE2 [17,18,95]. This predicted that cat ACE2 was suitable as the attachment site of the S-protein of SARS-CoV-2 [17,18,95]. The findings of these *in silico* studies were consistent with experimental studies [22,36-39] and with naturally infected cases of SARS-CoV-2 in cats [24,25,52,53,94]. This may also explain the susceptibility of cats to SARS-CoV-2 infection [24,25,52,53,94], and the ability of the virus to replicate and transmit between cats [22,36,37].

SARS-CoV-2 infections in *in vivo* studies [22,36-39], and mainly in naturally infected cases, did not result in clinical symptoms [96]. Although asymptomatic, thickening of the alveolar septa was found histopathologically, which indicated chronic lung inflammation [38]. Recently, an unusual clinical manifestation has been documented, which included severe myocarditis and impaired general health in cats infected by the B.1.1.7 variant of SARS-CoV-2 [97]. It was also reported previously in human patients that symptoms of acute myocarditis developed in more than 25% of critical cases because of SARS-CoV-2 infections [14]. A systematic review reported that cats developed variable mild to severe respiratory signs, with predominant presentations of sneezing and coughing, gastroenteritis (vomit and diarrhea), diminishing general health status (fever, lethargy, and lack of appetite), cardiovascular signs (cardiomyopathy, congestive heart failure, and ventricular arrhythmia), and neurological signs [96]. The unusual signs may relate to the accumulation of mutations in the SARS-CoV-2 genome, which led to changes in the virulence of the virus and result in unusual outcomes [97]. Therefore, further research is needed on SARS-CoV-2 mutations in humans and cats to increase awareness and suspicion in natural cases of SARS-CoV-2 infection, especially in asymptomatic cats.

#### **SARS-CoV-2 infections in dogs**

Experimental studies in dogs found that SARS-CoV-2 replicated in the respiratory tract of dogs, but animals may not transmit the virus to other dogs [22,37]. Several inoculated dogs were positive for viral RNA, thus indicating the presence of viral replication, but dogs did not shed the infectious virus [22,37]. In addition, antibodies against SARS-CoV-2 were detected in inoculated dogs but were undetectable in naive co-housed dogs [22,37].

The natural infection of SARS-CoV-2 in dogs was reported in Hong Kong for the first time from a household infected with COVID-19. The dogs were found to be positive for viral RNA and seroconverted to SARS-CoV-2 [23]. Interestingly, the SARS-CoV-2 genomes from both dogs were identical to the viral genome from a related human case [23]. In addition, a serological study in dogs during the Wuhan outbreak showed that 1.69% of the dogs' sera were positive for SARS-CoV-2 antibodies. The positive sera were collected from the owners with COVID-19, pet hospitals, and stray animals [98]. The same result in Thailand showed that 1.66% of the sera collected from dogs during the outbreak were positive to SARS-CoV-2 antibodies [92].

In Italy, an epidemiological survey on SARS-CoV-2 infection in dogs reported that viral RNA was not detected, but several dogs with COVID-19 positive or negative owner found positive for SARS-CoV-2 neutralizing antibodies [28]. In France and Croatia, the seroprevalence of SARS-CoV-2 in dogs with COVID-19 positive owners was 15.4% [93] and 43.9% [99] respectively, whereas in the United Kingdom from the unknown owner status, the seroprevalence was 1.4% [100].

Several cases of SARS-CoV-2 infection in dogs were also reported in Rio de Janeiro, Brazil, from a household with a confirmed COVID-19 infection [55] and from a stray dog [54]. As many as 31% of dogs from households with patients with positive COVID-19 were positively infected with SARS-CoV-2, and some showed positive outcomes for antibodies to SARS-CoV-2 [55].

The first confirmed case of SARS-CoV-2 in a dog in the USA was announced on June 2, 2020. A German shepherd dog, which lived with another dog and the owner who was COVID-19 positive, developed the symptoms of respiratory illness and tested positive for viral RNA and neutralizing antibodies to SARS-CoV-2 [86,101]. In addition, several SARS-CoV-2 infection cases were reported by the OIE in follow-up reports with the numbers of 4, 8, 9, 10, 11, 12, 13, 14, 16, 17, 18, 20, and 23 [59-61,69-72,74,78-86,89,102-107]. In Texas was found that 1.7% of dogs from infected COVID-19 households were positive for the viral RNA, and 11.9% were positive for neutralizing antibodies to SARS-CoV-2 [94]. A serological study in Minnesota, USA, from April to June 2020 showed that 0.98% of dogs were seropositive for the N-protein SARS-CoV-2 [102].

The S-protein of SARS-CoV-2 interacted with the ACE2 of dogs. The analysis of canine ACE2 compared with human ACE2 contained five amino acid changes. These same amino acid changes also occurred in pig ACE2. These included the residues Gln24Leu, Asp30Glu, His34Tyr, Met82Thr, and Asp38Glu [95]. Changes in Gln24Leu and His34Tyr resulted in failure of hydrogen bond formation and in the weakening of the stability of the interaction between ACE2 and

the S-protein of SARS-CoV-2 [103]. In contrast, the replacement of Asn90 residues with Asp resulted in a lack of N-glycosylation at position 90 [17,18,95]. *In silico* studies found the low susceptibility of dogs to SARS-CoV-2 infections [17,18,95]. In addition, no viral transmission was documented from inoculated animals to naive, close contact animals [22,37]. In the cases of natural infections, there was no confirmed evidence of COVID-19 transmission among dogs [23]. This suggests that dogs may be infected with SARS-CoV-2, but they have low susceptibility and have not transmitted the virus to other dogs [22,23].

### SARS-CoV-2 Infections in Wild Animals

#### SARS-CoV-2 infections in big cats

Natural infections of SARS-CoV-2 in big cats have been reported in the tiger (*Panthera tigris*) [29,30,89,104-106], lion (*Panthera leo*) [29,30,104,105], snow leopard (*Panthera uncia*) [86,106], and cougar (*Puma concolor*) [61]. The first confirmed SARS-CoV-2 case was reported in the Bronx Zoo, New York City, USA, in tigers on April 4, 2020, and in lions on April 15, 2020 [104,105]. Tigers and lions showed clinical signs, such as dry cough and some wheezing, but no respiratory distress. All animals with clinical signs improved and recovered. The sources of infection were assumed to be transmissions from the zookeepers who had no clinical signs (asymptomatic) [104,105]. Epidemiologic and genomic data from the tiger and lion showed a different genotype of SARS-CoV-2, which indicated human-to-animal transmission from two different sources [29,30]. Furthermore, viral RNA shedding was found in feces and respiratory secretions of infected animals and persisted in the feces for more than 4 weeks [29,30]. Based on the infection timeline, it was assumed that the virus was transmitted from zookeepers to animals and subsequently to other animals in the same cage [29,30].

Another case in Tennessee, USA, found that three Malayan tigers (*P. tigris tigris*) exhibited clinical signs, including mild coughing, lethargy, and inappetence; all tigers were confirmed positive for SARS-CoV-2. It seems that the tigers were infected by the transmission of SARS-CoV-2 from an infected human. All tigers recovered [89,106]. In addition, other natural infection cases of SARS-CoV-2 in big cats and in the snow leopard at the Louisville Zoo, USA, were detected in December 2020 [61] and at the San Diego Zoo, USA, in July 2021 [60]; additionally, there was a cougar case in Texas, USA, in February 2021 [59]. In mid-September 2021, three tigers and six lions at the Smithsonian National Zoo, USA, were presumed positive for SARS-CoV-2 after they presented mild respiratory symptoms, such as coughing and sneezing, lethargy, and decreased appetite [107].

Natural cases of SARS-CoV-2 in Katanga lions (*P. leo bleyenberghi*) were reported in the Barcelona Zoo (Catalonia, Spain) from November to December

2020 [64]. These four lions had respiratory symptoms, such as sneezing, coughing, and nasal discharge, and developed antibodies against SARS-CoV-2 [64].

Recently, two Sumatran tigers (*P. tigris sumatrae*) at Ragunan Zoo, Jakarta, Indonesia, were confirmed positive for SARS-CoV-2 by RT-PCR, on July 15, 2021. These big cats presented with mild respiratory symptoms, such as lethargy, sneezing, shortness of breath, mucus secretion from the nose, and decreased appetite [65,66]. In India, nine lions [62] and three [63] Asiatic lions (*P. leo persica*) were reported to be positive to SARS-CoV-2 Delta variant in the B.1.617.2 lineage during May-June 2021 [62,63].

The susceptibility of the tiger, lion, leopard, and puma was analyzed by *in silico* studies by comparing the ACE2 of these animals with the human ACE2. ACE2 receptors from the tiger, cougar, and leopard (*Panthera pardus*) identified four amino acids changes, which were Gln24Leu, Asp30Glu, Asp38Glu, and Met82Thr and had His34 and N-glycosylated Asp90, the same as those for humans and cats [95,103,108]. By contrast, in lions, apart from having the same four amino differences as cats, a mutation of Asn90 to Asp resulted in the loss of N-glycosylation at site 90 [98]. Furthermore, a mutation was reported in His34 to Ser was also reported [95]. The His34 residue was considered a critical residue associated with the susceptibility of lions and tigers to SARS-CoV-2 infections [103]. The His34 to Ser mutation was predicted to decrease the binding stability between ACE2 and the SARS-CoV-2 S-protein [103]. This suggested that animals with His34Ser mutations had a lower susceptibility than animals with His34 [103].

Almost all animals had respiratory tract symptoms, with or without general symptoms of disease, such as lethargy or loss of appetite [29,30,59-61,65,66,89,104-106]. In addition, up to 96.5% of animals had a cough and 79% of animals had sneezing symptoms [96]. The appearance of the clinical signs may be explained by the ACE2 expressions in the ciliated bronchial epithelium cells from tigers and lions and in the endothelial blood vessels within the alveolar septa in tigers [109]. In view of the expressions of ACE2 in the respiratory tracts of big cats [109], the increasing number of natural infections of SARS-CoV-2 in these animals and the transmission of the virus from asymptomatic carriers [29,30,59-61,65,66,89,104-107], a SARS-CoV-2 vaccination program should be implemented in these big cats. There should be more concern about SARS-CoV-2 surveillance in wild animals to minimize the spread of SARS-CoV-2 within the animal population.

#### SARS-CoV-2 infections in deer

The susceptibility of deer to the virus was investigated in studies *in vitro* and *in vivo*, as well as *in silico*. An *in vitro* study was performed in deer lung cells infected with SARS-CoV-2 isolate TGR/NY/20 [43] and human/USA/WA1/2020 [44]. It was found that

SARS-CoV-2 replicated in white-tailed deer (*O. virginianus*) and mule deer (*Odocoileus hemionus*) lung cells [43,44], whereas the virus did not replicate in elk (*Cervus canadensis*) lungs cells [44].

Furthermore, in an *in vivo* study, SARS-CoV-2 was replicated in white-tailed deer fawns [43] and adult deer [44] and both groups of animals experienced subclinical viral infections [43,44]. Viral RNA was detected in nasal secretions and feces in fawns for longer periods than those in adult deer [43,44], in fawns during days 1-21 post-infection [43], and in adults during days 1-10 post-infection [44]. The virus replicated in the upper respiratory and gastrointestinal tracts and was shed from nasal, oral, and rectal swabs [44].

Viral transmission occurred from inoculated animals to indirect contact animals [43,44]. Viral RNA was detected in nasal, oral, or rectal swabs of co-housed animals [44]. Infectious viruses were detected in nasal secretions and the feces from indirect contact animals at days 2-7 post-infection [43]. Both inoculated and non-inoculated deer developed neutralizing antibodies [43]. Furthermore, despite the horizontal transmission between inoculated animals and indirect contact animals, the vertical transmission from the adult female deer to the fetus was also reported [44].

*In vitro* and *in vivo* studies showed a high susceptibility of deer to SARS-CoV-2 infections [43,44]. Recently, a serological survey during January-March 2021 in the USA (Michigan, Pennsylvania, Illinois, and New York states) has found SARS-CoV-2 antibodies in 40% of the wild white-tailed deer population [31]. In addition, antibodies against SARS-CoV-2 were detected in one and three sera samples in 2019 and 2020, respectively; however, these samples showed low percent inhibition values [31]. At present, the first confirmation of SARS-CoV-2 in the wild white-tailed deer was announced in Ohio, USA, on August 27, 2021 [110].

White-tailed deer, reindeer (*Rangifer tarandus*), and Père David's deer (*Elaphurus davidianus*) were predicted to have a high susceptibility to SARS-CoV-2 infections [108]. Homology analyses of deer ACE2 revealed high similarities to humans ACE2 [108]. It showed four different amino acid residues (Asp30Glu, Leu79Met, Met82Thr, and Asn322His) and a Lys31Asn residue for Père David's deer [108]. In addition, analyses of the interaction between ACE2 of these three species of deer and RBD of SARS-CoV-2 exhibited a high-binding score and indicated high susceptibility to viral infection [108]. Considering these *in silico* studies [108], the high susceptibility and transmissibility to SARS-CoV-2 infection [43,44], the high seroprevalence of SARS-CoV-2 in the wild white-tailed deer population [31], and the first confirmed SARS-CoV-2 infection case in wild white-tailed deer in the world, it is necessary to monitor the deer, its predators, and other wildlife populations [31].

## SARS-CoV-2 Infections in Farm Animals

### SARS-CoV-2 infections in cattle and sheep

In cattle (*B. taurus*), an *in vitro* study was performed in the bovine cell line, including turbinate, trachea normal, pulmonary artery, fetal bovine lung, and fetal bovine kidney cells. Cell lines were infected with SARS-CoV-2 isolate TGR/NY/20. This indicated that SARS-CoV-2 did not replicate [40]. However, another *ex vivo* study in organ cultures of respiratory tract cells demonstrated that SARS-CoV-2 replicated in lung and trachea cells. The respiratory tract was also shown immunoreactive to the polyclonal antibody of ACE2 [41].

An *in vivo* study of SARS-CoV-2 infection in cattle showed that the virus replicated but was not transmitted [40,41]. Six-week-old calves exhibited mild symptoms, such as a high temperature and mild cough. The virus replicated, but viral shedding was not found. The calves developed neutralizing antibodies against SARS-CoV-2, but this antibody titer did not persist for more than 21 days [40]. Another study in older calves revealed that the virus replicated, but the calves did not shed the virus and there were no clinical signs [42].

Homogenetic analyses of ACE2 of the family Bovidae, including cattle (*B. taurus*), water buffalo (*Bubalus bubalis*), wild goat (*Capra aegagrus*), goat (*Capra hircus*), and sheep (*O. aries*), with human ACE2 exhibited high similarity. This analysis identified four amino acid residues different from those of human ACE2: Asp30Glu, Leu79Met, Met82Thr, and Asn322Tyr. Furthermore, the evaluation of the binding contact between ACE2 of those animals with RBD in the S-protein of SARS-CoV-2 predicted medium susceptibility to SARS-CoV-2 infection, at the same level as documented in the cat [108]. In addition, ACE2 receptors were expressed in the bronchiole epithelia of cattle and sheep but not in the nasal mucosa and alveoli [109]. By contrast, ACE2 receptors in cats were expressed in alveoli and Type I pneumocytes [109]. However, an *in vivo* study found that the infectious virus was not detected in cattle. This may indicate that cattle had low susceptibility to SARS-CoV-2 infections [40,42].

The susceptibility of sheep to SARS-CoV-2 infection was investigated in *ex vivo* organ cultures of respiratory tract cells infected with SARS-CoV-2 with D614 and SARS-CoV-2 with D614G. The results demonstrated that sheep lung and trachea cells exhibited ACE2 receptors and thus supported the replication of both SARS-CoV-2 variants [41]. This indicates that SARS-CoV-2 can infect sheep, but further *in vivo* studies are needed to confirm the susceptibility of sheep to SARS-CoV-2 infection. Likewise, research on the susceptibility of other ruminant groups to SARS-CoV-2 infections still requires further *in vitro* and *in vivo* research studies.

### SARS-CoV-2 infections in pigs

The susceptibility of pigs to SARS-CoV-2 infections was investigated *in vitro* using swine cell lines. Swine testicular and kidney cells (SK-6 and PK-15) [45,46] supported SARS-CoV-2 replication. In contrast, SARS-CoV-2 did not replicate in *ex vivo* respiratory organ cultures from pigs [41].

*In vivo* studies in domesticated pigs (*S. scrofa domestica*) found no viral replication and transmission of SARS-CoV-2 from inoculated animals to contact-naive animals [22,45-47]. Viral RNA was not detectable in oropharyngeal and rectal swabs from pigs inoculated with  $10^5$  PFU of CTan-H or naive animals at all-time points, and there were no antibodies to SARS-CoV-2 [22]. Pigs infected with  $10^5$  TCID<sub>50</sub> of 2019\_nCoV Muc-IMB-1 yielded the same results [45]. Inoculated and naive-contact animals had no clinical signs. Viral RNA, antibodies, and organ lesions after necropsy were also not detected [45]. Both those studies challenged pigs intra-nasally [22,45]. Another study that carried out the challenge through the intranasal, oral, and intratracheal routes simultaneously obtained the same results, despite the higher dose (dose  $10^6$  TCID<sub>50</sub> of SARS-CoV-2) [46]. Meanwhile, pigs inoculated with  $10^{5.8}$  TCID<sub>50</sub> of SARS-CoV-2 intravenously and intramuscularly were shown to have low levels of anti-SARS-CoV-2 antibodies, despite the fact that they did not show clinical signs, and viral RNA was not detected in nasal or rectal swabs [47].

Although the previous studies that challenged pigs with SARS-CoV-2 through intranasal, intratracheal, oral, intramuscular, and intravenous routes showed that pigs were not susceptible to SARS-CoV-2 infections [22,45-47], there were two research groups reported different results [48,49]. First, pigs aged 8 weeks were challenged with  $10^6$  PFU/animal of SARS-CoV-2 isolate hCoV-19/Canada/ON-VIDO-01/2020 via the nasal and pharynx routes. It was the first study that detected low-level viral RNA in nasal washing and oral fluids after inoculation. However, it was not detectable in other swab samples (oral, nasal, and rectal swabs). The study found neutralizing antibodies against SARS-CoV-2 at low levels in two pigs. One pig presented cough and mild depression symptoms from day 1 to 4 post-infection. The infectious virus was detected in this pig in the submandibular lymph node at day 13 post-infection [48]. A second study on pigs involved infections with  $6.8 \times 10^6$  TCID<sub>50</sub> of the SARS-CoV-2 isolate TGR/NY/20 through the intratracheal, intranasal, and intravenous routes. Viral RNA in nasal/oral and rectal swabs and neutralizing antibodies against SARS-CoV-2 from all groups of administration routes were detectable but transient. Furthermore, some tissues (tonsils, mandibular lymph node, and tracheobronchial lymph node) from inoculated animals showed weak positivity for viral RNA, but the infectious viruses were not isolated successfully. That study proved that

inoculation of the virus through these routes could not produce the infectious virus, and there were no viral transmissions from inoculated animals to naive-contact animals [49].

Several studies predicted the susceptibility of pigs to SARS-CoV-2 infections based on comparisons of pig ACE2 with human ACE2 [95,108]. These studies found five amino acid changes in pig ACE2, as in dogs [95,108]. There are mutations of Gln24Leu, Asp30Glu, and Met82Thr in pigs and dogs [95,108], His34 to Leu in pigs and Tyr in dogs, and Asn90 to Thr in pigs and Asp in dogs [95,108]. Mutations of Gln24 to Leu and His34 to Leu or Tyr led to the failure of hydrogen bond formation between the SARS-CoV-2 S-protein and porcine ACE2 receptors [95,108]. In addition, mutations of Asn90 to Thr or Asp led to a lack of glycosylation site at position 90 [95,108]. Based on these *in silico* studies, pigs and dogs exhibited low susceptibility to SARS-CoV-2 [95,108], but dogs have been shown infected with SARS-CoV-2 naturally [24,54,55,86,93,101].

*Ex vivo* [41] and *in vivo* studies [22,45-47] in swine respiratory tract cells found no SARS-CoV-2 replication. On the contrary, infection with higher doses showed weak positive viral RNA in swabs [48,49], and SARS-CoV-2 RNA and protein of inoculated animals were undetectable in respiratory tract cells [41,46,48]. The distribution of ACE2 protein on the tissues showed no expression in the upper and lower respiratory tract cells [41,109], but the mRNA type was found to be weakly expressed [49]. However, it was overexpressed in the small intestine [109] and kidney [41,49]. This may explain the fact that SARS-CoV-2 replicated in kidney cells [45,46] but not in the respiratory tract cells of pigs [41,45,46,49]. Those experimental studies were consistent with *in silico* predictions and indicated that pigs have a low susceptibility to SARS-CoV-2 infections [108].

### SARS-CoV-2 infections in minks

The first case of natural infection of SARS-CoV-2 in minks (*Neovison vison*) was reported in two farms in the Netherlands in April 2020 [34]. These animals revealed severe respiratory diseases and increased mortality. The clinical signs included breathing difficulties and nasal exudate. SARS-CoV-2 viral RNA and viral antigen were detected in the upper and lower respiratory tracts [34]. Histopathological features included the thickening and degeneration of alveolar septa, which indicated acute severe interstitial pneumonia or diffuse alveolar damage [34,56]. Before the SARS-CoV-2 outbreak occurred in the mink farm, a worker in the farm tested positive for SARS-CoV-2, indicating the probable transmission from the human to mink [34].

In addition, SARS-CoV-2 infected minks were reported in Denmark around June 2020 [111]. Similar findings were reported in several countries in Europe, which included Spain in July 2020 [112,113],



Italy in August 2020 [112,113], Sweden in October 2020, Greece, France, Poland, and Lithuania in November 2020, the second infection in a mink farm in Poland on 30 January 2021, and in Latvia in April 2021 [58,112,113]. In the Netherlands and Denmark, the virus spread rapidly among minks, resulting in respiratory diseases and increased mortality [35,111].

The first case was reported in August 2020 in two commercial mink farms in the USA. The clinical findings included respiratory signs and sudden death. It was assumed that a mink was infected from SARS-CoV-2 infected people who contacted the mink and the virus spread it among minks in these farms [87]. A total of 177,357 suspected minks and the deaths of 16,130 minks due to SARS-CoV-2 infections were reported in mink farms in Utah, Michigan, Wisconsin, and Oregon, USA, from June to October 2020, as OIE reported in the follow-up reports No. 15, 16, 19, 20, 21, 22, 25, and 26 [71-73,82,87-90].

The SARS-CoV-2 genome in the mink farm in the Netherlands had a high diversity [35]. There were five clusters, among which three clusters (A, C, and E) contained the mutation of aspartate 614 to glycine (D614G) that was found in general human populations and in cases related to minks [35]. In Denmark, mutations that occurred in the ORF1b gene were mutations of threonine 730 to isoleucine (T730I) and proline 314 to leucine (P314L). In contrast, in the ORF3a gene, there was a mutation of histidine 182 to tyrosine (H182Y). Finally, in the nucleoprotein gene, there were mutations of arginine 203 to lysine and glycine 204 to arginine [111]. In addition, D614G and Y453F mutations occurred in the spike gene [111]. The SARS-CoV-2 variant T730I was found in humans and in the mink population in Jutland, Denmark, and in human from New Zealand [111]. A H182Y mutation within ORF3a appeared in all minks in Denmark and in human cases related to the mink. Even if it was a rare mutation, it was also found in a mink farm in the Netherlands [111]. Recently, the new variant of SARS-CoV-2 that contained the deletions of histidine 69 (H69) and valine 70 (V70) has been reported. Some mutations developed in mink farms and in 12 humans with COVID-19 who lived around the mink farms in Jutland included Y453F, D614G, isoleucine 692 to valine (I692V), and methionine 1229 to isoleucine (M1229I) [57]. The deletion of H69 and V70 within the spike gene occurred in mink farms probably as an adaptation of the virus to increase its binding ability to the receptor [114]. The same finding was revealed in Poland [115]. Mutations occurred in the spike gene, which resulted in alterations of the amino acids glycine 75 to valine, methionine 177 to threonine, cysteine 1247 to phenylalanine, and contained the amino acid mutation Y453F [115], as previously reported in the mink farm in Denmark [57,111].

D614G and Y453F are two interesting mutations in the S-protein of SARS-CoV-2. These are specific mutations found in the mink and are related to the

mutations found in humans on the mink farm [35,111]. Mutations of D614G in S-protein were found predominantly in the human population, in the mink farm in Denmark and the Netherlands [35,111]. Furthermore, Y453F mutation was found in mink farms in the Netherlands and was related to human cases in mink farms in Denmark [111]. The change of aspartate residue at position site 614 to glycine and the tyrosine residue at position site 453 to phenylalanine were a form of virus adaptation to allow the virus to enter host cells; this efficiently increased ACE2 binding in minks and humans [116]. In addition, the mutation of Y453F reduced the efficiency of antibody therapy and convalescent serum/plasma therapy from patients with COVID-19, thus reducing the success of therapy and increasing the risk of death in patients [116].

The SARS-CoV-2 genome obtained from the mink samples was highly similar to humans associated with mink farms in the Netherlands and Denmark [35,111], indicating viral transmissions from the mink workers to the animals [35]. Subsequently, the spreading of the virus among minks in the farms occurred by inhalation of spray droplets from sneezing and coughing or inhalation of aerosol microparticles (<5 µm) that contained infectious viruses [117,118]. This has been proven by finding viral RNA in dust samples collected using stationary air sampling (over 5-6 h periods) in the mink farm during the outbreak [34]. Furthermore, based on genomic and epidemiological studies, it appeared that SARS-CoV-2 was transmitted from humans to minks and spread among minks following the appearance of several new mutations; it was then transmitted back to humans, as was also observed in the Netherlands and Denmark [35,111], making it possible to transfer the virus to other sites [112].

The spread of SARS-CoV-2 from the mink to the surrounding environment or to other animals that live at the farms is also possible [112,119]. This is based on the finding of viral RNA in airborne dust collected at locations 2-3 m from farms, in fur and straw from infected farms, and in the feet of seagulls that often forage on mink farms in Denmark, thus making it possible to transfer the virus to other sites [112]. The dogs and cats on the farm were also positive for viral RNA, and some dogs and cats had antibodies to SARS-CoV-2 [112]. A study from the Netherlands [119] reported that viral RNA was identified in stray cats that lived near farm sites and cats and dogs that lived on the farm [119]. The authors presumed that the stray cats were infected by the minks, but the source of viral infections in dogs has not been determined [119].

SARS-CoV-2 transmission from humans to minks, minks to minks, and minks to humans or other animals was found [35,111,112,119]. In addition, indirect transmission through dust or objects around the mink farm contains the active virus [58,119]. There was evidence of the possibility of the emergence of new strains because of new mutations or

accumulations of mutations in the viral genome in the mink group, which were faster and more virulent [57,111,115,116]. Hence, it is necessary to consider mitigation strategies to manage outbreaks in animals, humans globally, especially those related to transmission cases among animals, from animals to humans, and humans to animals. It is also crucial to protect stray animals and wild animals around mink farms.

#### SARS-CoV-2 infections in poultries

To evaluate susceptibility of poultries to SARS-CoV-2 infection, several experimental studies have been conducted, including in chickens (*Gallus gallus domesticus*), turkeys (*Meleagris gallopavo*), pekin ducks (*Anas platyrhynchos domesticus*), Japanese quails (*Coturnix japonica*), and in white Chinese geese (*Anser cygnoides*) [22,45,50]. These domesticated fowl were infected intra-nasally or oculo-oronasally and later introduced to naive animals. All studies reported that viral RNA was not detected in any oropharyngeal and cloacal swabs collected from inoculated animals or naive animals. In addition, all these birds were seronegative for SARS-CoV-2 [22,45,50]. All animals showed no clinical signs during the study, and any lesion was detected at necropsy [45,50]. Similarly, embryonated chicken eggs (ECEs) were usually used for isolation, and the laboratory host system in the vaccine production exhibited no viral replication in ECEs [45,50]. All these studies on poultry and ECEs showed that the viral RNA cannot be replicated and transmitted among birds [22,45,50].

Despite experimental studies, it was found that chickens that had indirect contact with the mink farm outbreak were negative for SARS-CoV-2 viral RNA [112,119]. It was also reported that wild birds trapped in the mink farms affected, including hundreds of seagulls with other birds, including one hooded crow (*Corvus cornix*), a jackdaw (*Corvus monedula*), and a common kestrel (*Falco tinnunculus*), were found negative for SARS-CoV-2 RNA [112]. This was in accordance with the predictions of *in silico* studies [95]. The class Aves, including chickens and ducks, had ACE2 receptors that did not match the S-protein of SARS-CoV-2 [95]. Analyses conducted to compare the chicken and duck ACE2 receptors with human ACE2 receptors showed that the receptors of these avian species contained ten amino acids changes and lacked the N-glycosylation at position site 90 [95]. These changes affected the amino acid residue involved in the binding of ACE2 to the SARS-CoV-2 S-protein, in chicken including Gln24Glu, His34Val, Leu79Asn and Met82Arg, and Gly354Asn, and in ducks was His34Val, Leu79Asn, Met82Asn, and Gly354Asn [95]. This change also occurred in Tyr83Phe, which resulted in the failure of hydrogen bond formation, and in Asp30Ala, which resulted in the lack of salt bridge formation [95]. Therefore, these findings may explain the inability of ACE2 receptors in the bird group to bind to the S-protein of the SARS-CoV-2.

These findings suggest that poultry are not susceptible to SARS-CoV-2 infections [22,45,50].

#### SARS-CoV-2 infections in other animals

SARS-CoV-2 infection has been reported in several animals. Gorillas (*Gorilla gorilla*) at the San Diego Zoo, USA, were found positive for SARS-CoV-2 on January 11, 2021. Despite appearing to have a mild cough, stuffy nose, and lethargy symptoms, they recovered [91]. Confirmation of COVID-19 was reported in Asian small-clawed otters (*Aonyx cinereus*) in Georgia, USA, in April 2021 [120]. These otters, which includes in the family Mustelidae that the same family with minks, showed clinical signs, such as sneezing, runny noses, mild lethargy, and coughing [120]. Recently, several animals have been reported to be infected with SARS-CoV-2, including animals at a zoo in Illinois, USA, that was a binturong (*Arctictis binturong*) and a fishing cat (*Prionailurus viverrinus*) on October 5, 2021, [121] and a South American coati (or coatimundi, *Nasua nasua*) on October 14, 2021 [122]. Furthermore, two hyenas at Denver Zoo in Colorado, USA [123] were tested positive for SARS-CoV-2 with other animals in the zoo, including lions and tigers, on November 5, 2021 [123]. The two hippos at a zoo in Antwerp, Belgium were positive for SARS-CoV-2 infections on December 6, 2021 [124].

Animals from infected mink farms, such as chickens, rabbits, and horses, tested negative for SARS-CoV-2 [112]. PCR-negative outcomes for SARS-CoV-2 were also found in a group of wild animals collected in the areas around the infected mink farms from October to November 2020 in Denmark, including red foxes (*Vulpes vulpes*), badgers (*Meles meles*), least weasel (*Mustela nivalis*), polecats (*Mustela putorius*), otter (*Lutra lutra*), beech martens (*Martes foina*), and raccoon dogs (*Nyctereutes procyonoides*), as well as in feral mink (*N. vison*) [112]. SARS-CoV-2 infections have not been reported in other wild animals, pets, and farm animals that have close contact with humans, such as horses, goats, camels, and buffaloes, have not been reported. This requires further investigation in terms of both the detection of viral RNA and serological surveys.

Recently, there have been many reported cases of COVID-19 in animals. To prevent SARS-CoV-2 infections in various animals, both pets and wild and farm animals, vaccines have been developed, including a vaccine from Zoetis company, Carnivac-Cov, and the LinearDNA™ COVID-19 vaccine [125-127]. Zoetis has developed a subunit recombinant vaccine for the SARS-CoV-2 S-protein for wild animals. It has been used to vaccinate some species of wild animals in several zoos and sanctuaries in the USA and Canada, including orangutans, bonobos, hyenas, chimpanzees, and lions [125,126]. Thus, Russia has developed Carnivac-Cov, an inactivated vaccine, and has been on clinical trials in dogs, cats, foxes, and

minks [125]. The Linear DNA™ COVID-19 vaccine has been developed by Applied DNA Sciences (USA) and EvviVax (Italy) for use in domestic felines [127]. The safety and immunogenicity of this vaccine in cats showed to be well tolerated and induced high titers of SARS-CoV-2 neutralizing antibodies [127], while the safety and immunogenicity in minks are currently in progress of research [128]. Furthermore, successful immunization of animals could protect animals from SARS-CoV-2 infections and prevent virus transmission among animals and cross-species. Therefore, it reduces the risk of the emergence of new mutations of SARS-CoV-2 [125,129].

## Conclusion

The susceptibility of animals to SARS-CoV-2 is very different depending on the family. Felines, including domestic cats and big cats, are susceptible species where virus transmission between animals has also been detected. Other wild animals that were found to be infected as natural infections in the zoos were gorillas, otters, a binturong, a fishing cat, a coatimundi, hyenas, and hippos. Livestock, such as cattle, sheep, and pigs, have a low susceptibility to SARS-CoV-2 infections, whereas poultries have been shown to be less susceptible to SARS-CoV-2 infection.

In most cases, infection of SARS-CoV-2 in animals was through close contact with humans, including in domesticated animals, big cats, and other wild animals in zoos. This also occurred in white-tailed deer and minks. In white-tailed deer, the virus can transmit to other deer that are in close contact or to its fetus experimentally. Furthermore, it is suspected that SARS-CoV-2 may have spread to the white-tailed deer population naturally with the finding that the seroprevalence of SARS-CoV-2 in the deer population was quite high. In minks, the virus infections were being transmitted from humans and be spread among minks and then undergone adaptation and spread back to humans. Presumably, the virus in minks and white-tailed deer were also possible to be transmitted to other animals because of the large number of infected animals and the high seroprevalence rate in these two animal species.

When infecting humans or animals, viruses generate several mutations and accumulate; then the mutation will be transmitted to other humans or animals. Some mutations increase the level of viral virulence, and some cause resistance to antibodies or convalescent plasma therapy. Therefore, it is necessary to increase the awareness of rapidly mutating viruses and prepare various forms of appropriate therapies and treatments. Not only do vaccines need to be developed, but also research related to the development of antivirals and therapeutic management, as well as comprehensive strategies for mitigating infectious and dangerous diseases are also necessary. This knowledge may contribute to the management of the SARS-CoV-2 pandemic in humans and animals.

## Authors' Contributions

GM: Conception of idea and drafted and revised the manuscript. GM, AR, and RI: Literature search. AR and RI: Editing of the manuscript. IR and IdB: Conception of idea, literature search, and reviewing the manuscript. All authors read and approved the final manuscript.

## Acknowledgments

The authors are thankful to Universitas Airlangga, Surabaya, Indonesia, for the language editing support. The authors did not receive any funds for this review.

## Competing Interests

The authors declare that they have no competing interests.

## Publisher's Note

Veterinary World remains neutral with regard to jurisdictional claims in published institutional affiliation.

## References

- Huang, C., Wang, Y., Li, X., Ren, L., Zhao, J., Hu, Y., Zhang, L., Fan, G., Xu, J., Gu, X., Cheng, Z., Yu, T., Xia, J., Wei, Y., Wu, W., Xie, X., Yin, W., Li, H., Liu, M., Xiao, Y., Gao, H., Guo, L., Xie, J., Wang, G., Jiang, R., Gao, Z., Jin, Q., Wang, J. and Cao, B. (2020) Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet*, 395(10223): 497-506.
- Worldometer. Coronavirus. Available from: <https://www.worldometers.info/coronavirus> Retrieved on 19-02-2022.
- Gorbalenya, A.E., Baker, S.C., Baric, R.S., de Groot, R.J., Drosten, C., Gulyaeva, A.A., Haagmans, B.L., Lauber, C., Leontovich, A.M., Neuman, B.W., Penzar, D., Perlman, S., Poon, L.L.M., Samborskiy, D.V., Sidorov, I.A., Sola, I. and Ziebuhr, J. (2020) The species Severe acute respiratory syndrome-related coronavirus: Classifying 2019-nCoV and naming it SARS-CoV-2. *Nat. Microbiol.*, 5(4): 536-544.
- Zhou, P., Yang, X.L., Wang, X.G., Hu, B., Zhang, L., Zhang, W., Si, H.R., Zhu, Y., Li, B., Huang, C.L., Chen, H.D., Chen, J., Luo, Y., Guo, H., Jiang, R.D., Liu, M.Q., Chen, Y., Shen, X.R., Wang, X., Zheng, X.S., Zhao, K., Chen, Q.J., Deng, F., Liu, L.L., Yan, B., Zhan, F.X., Wang, Y.Y., Xiao, G.F. and Shi, Z.L. (2020) A pneumonia outbreak associated with a new coronavirus of probable bat origin. *Nature*, 579(7798): 270-273.
- Zhang, T., Wu, Q. and Zhang, Z. (2020) Probable pangolin origin of SARS-CoV-2 associated with the COVID-19 outbreak. *Curr. Biol.*, 30(8): 1578.
- do Vale, B., Lopes, A. P., Fontes, M., Silvestre, M., Cardoso, L. and Coelho, A.C. (2021) Bats, pangolins, minks, and other animals villains or victims of SARS-CoV-2? *Vet. Res. Commun.*, 45(1): 1-19.
- Caly, L., Druce, J., Roberts, J., Bond, K., Tran, T., Kostecki, R., Yoga, Y., Naughton, W., Taiaroa, G., Seemann, T., Schultz, M.B., Howden, B.P., Korman, T.M., Lewin, S.R., Williamson, D.A. and Catton, M.G. (2020). Isolation and rapid sharing of the 2019 novel coronavirus (SARS-CoV-2) from the first patient diagnosed with COVID-19 in Australia. *Med. J. Aust.*, 212(10): 459-462.
- Spiteri, G., Fielding, J., Diercke, M., Campese, C., Enouf, V., Gaymard, A., Bella, A., Sognamiglio, P., Sierra Moros, M.J., Riutort, A.N., Demina, Y.V., Mahieu, R., Broas, M., Bengnér, M., Buda, S., Schilling, J., Filleul, L., Lepoutre, A., Saura, C., Mailles, A., Levy-Bruhl, D., Coignard, B., Bernard-Stoecklin, S., Behillil, S., van der

- Werf, S., Valette, M., Lina, B., Riccardo, F., Nicastrì, E., Casas, I., Larrauri, A., Salom-Castell, M., Pozo, F., Maksyutov, R.A., Martin, C., Van Ranst, M., Bossuyt, N., Siira, L., Sane, J., Tegmark-Wisell, K., Palmérus, M., Broberg, E.K., Beauté, J., Jørgensen, P., Bundle, N., Pereyaslov, D., Adlhoeh, C., Pukkila, J., Pebody, R., Olsen, S. and Ciancio, B.C. (2020) First cases of coronavirus disease 2019 (COVID-19) in the WHO European Region, 24 January to 21 February 2020. *Euro. Surveill.*, 25(9): 2000178.
9. Gonzalez-Reiche, A.S., Hernandez, M.M., Sullivan, M.J., Ciferri, B., Alshammari, H., Obla, A., Fabre, S., Kleiner, G., Polanco, J., Khan, Z., Albuquerque, B., van de Guchte, A., Dutta, J., Francoeur, N., Melo, B.S., Oussenko, I., Deikus, G., Soto, J., Sridhar, S.H., Wang, Y.C., Twyman, K., Kasarskis, A., Altman, D.R., Smith, M., Sebra, R., Aberg, J., Krammer, F., García-Sastre, A., Luksza, M., Patel, G., Paniz-Mondolfi, A., Gitman, M., Sordillo, E.M., Simon, V. and van Bakel, H. (2020) Introductions and early spread of SARS-CoV-2 in the New York city area. *Science*, 369(6501): 297-301.
10. Giandhari, J., Pillay, S., Wilkinson, E., Tegally, H., Sinaisky, I., Schulz, M., Lourenço, J., Chimukangara, B., Lessells, R., Moosa, Y., Gazy, I., Fish, M., Singh, L., Sedwell Khanyile, K., Fonseca, V., Giovanetti, M., Alcantara, L.C.J., Petruccione, F. and de Oliveira, T. (2021) Early transmission of SARS-CoV-2 in South Africa: An epidemiological and phylogenetic report. *Int. J. Infect. Dis.*, 103: 234-241.
11. Wu, F., Zhao, S., Yu, B., Chen, Y.M., Wang, W., Song, Z.G., Hu, Y., Tao, Z.W., Tian, J.H., Pei, Y.Y., Yuan, M.L., Zhang, Y.L., Dai, F.H., Liu, Y., Wang, Q.M., Zheng, J.J., Xu, L., Holmes, E.C. and Zhang, Y.Z. (2020) A new coronavirus associated with human respiratory disease in China. *Nature*, 579(7798): 265-269.
12. Wrapp, D., Wang, N., Corbett, K.S., Goldsmith, J.A., Hsieh, C.L., Abiona, O., Graham, B.S. and McLellan, J.S. (2020) Cryo-EM structure of the 2019-nCoV spike in the prefusion conformation. *Science*, 367(6483): 1260-1263.
13. Wan, Y., Shang, J., Graham, R., Baric, R.S. and Li, F. (2020) Receptor recognition by the novel coronavirus from Wuhan: An analysis based on decade-long structural studies of SARS coronavirus. *J. Virol.*, 94(7): e00127-20.
14. Clerkin, K.J., Fried, J.A., Raikhelkar, J., Sayer, G., Griffin, J.M., Masoumi, A., Jain, S.S., Burkhoff, D., Kumaraiah, D., Rabbani, L., Schwartz, A. and Uriel, N. (2020) COVID-19 and cardiovascular disease. *Circulation*, 141(20): 1648-1655.
15. Lan, J., Ge, J., Yu, J., Shan, S., Zhou, H., Fan, S., Zhang, Q., Shi, X., Wang, Q., Zhang, L. and Wang, X. (2020) Structure of the SARS-CoV-2 spike receptor-binding domain bound to the ACE2 receptor. *Nature*, 581(7807): 215-220.
16. Zou, X., Chen, K., Zou, J., Han, P., Hao, J. and Han, Z. (2020) Single-cell RNA-seq data analysis on the receptor ACE2 expression reveals the potential risk of different human organs vulnerable to 2019-nCoV infection. *Front. Med.*, 14(2): 185-192.
17. Qiu, Y., Zhao, Y.B., Wang, Q., Li, J.Y., Zhou, Z.J., Liao, C.H. and Ge, X.Y. (2020) Predicting the angiotensin converting enzyme 2 (ACE2) utilizing capability as the receptor of SARS-CoV-2. *Microbes Infect.*, 22(4-5): 221-225.
18. Luan, J., Lu, Y., Jin, X. and Zhang, L. (2020) Spike protein recognition of mammalian ACE2 predicts the host range and an optimized ACE2 for SARS-CoV-2 infection. *Biochem. Biophys. Res. Commun.*, 526(1): 165-169.
19. Cao, Y., Sun, Y., Tian, X., Bai, Z., Gong, Y., Qi, J., Liu, D., Liu, W. and Li, J. (2020) Analysis of ACE2 gene-encoded proteins across mammalian species. *Front. Vet. Sci.*, 7: 457.
20. Stout, A.E., André, N.M., Jaimes, J.A., Millet, J.K. and Whittaker, G.R. (2020) Coronaviruses in cats and other companion animals: Where does SARS-CoV-2/COVID-19 fit? *Vet. Microbiol.*, 247: 108777.
21. Lam, S.D., Bordin, N., Waman, V.P., Scholes, H.M., Ashford, P., Sen, N., van Dorp, L., Rauer, C., Dawson, N.L., Pang, C., Abbasian, M., Sillitoe, I., Edwards, S., Fraternali, F., Lees, J.G., Santini, J.M. and Orengo, C.A. (2020) SARS-CoV-2 spike protein predicted to form complexes with host receptor protein orthologues from a broad range of mammals. *Sci. Rep.*, 10(1): 16471.
22. Shi, J., Wen, Z., Zhong, G., Yang, H., Wang, C., Huang, B., Liu, R., He, X., Shuai, L., Sun, Z., Zhao, Y., Liu, P., Liang, L., Cui, P., Wang, J., Zhang, X., Guan, Y., Tan, W., Wu, G., Chen, H. and Bu, Z. (2020) Susceptibility of ferrets, cats, dogs, and other domesticated animals to SARS-coronavirus 2. *Science*, 368(6494): 1016-1020.
23. Sit, T., Brackman, C.J., Ip, S.M., Tam, K., Law, P., To, E., Yu, V., Sims, L.D., Tsang, D., Chu, D., Perera, R., Poon, L. and Peiris, M. (2020) Infection of dogs with SARS-CoV-2. *Nature*, 586(7831): 776-778.
24. Barrs, V.R., Peiris, M., Tam, K.W.S., Law, P.Y.T., Brackman, C.J., To, E.M.W., Yu, V., Chu, D., Perera, R. and Sit, T. (2020) SARS-CoV-2 in quarantined domestic cats from COVID-19 households or close contacts, Hong Kong, China. *Emerg. Infect. Dis.*, 26(12): 3071-3074.
25. Garigliany, M., Van Laere, A.S., Clercx, C., Giet, D., Escriviou, N., Huon, C., van der Werf, S., Eloit, M. and Desmecht, D. (2020) SARS-CoV-2 natural transmission from human to cat, Belgium, March 2020. *Emerg. Infect. Dis.*, 26(12): 3069-3071.
26. Sailleau, C., Dumarest, M., Vanhomwegen, J., Delaplace, M., Caro, V., Kwasiborski, A., Hordel, V., Chevaillier, P., Barbarino, A., Comtet, L., Pourquier, P., Klonjowski, B., Manuguerra, J.C., Zientara, S. and Le Poder, S. (2020) First detection and genome sequencing of SARS-CoV-2 in an infected cat in France. *Transbound. Emerg. Dis.*, 67(6): 2324-2328.
27. Zhang, Q., Zhang, H., Gao, J., Huang, K., Yang, Y., Hui, X., He, X., Li, C., Gong, W., Zhang, Y., Zhao, Y., Peng, C., Gao, X., Chen, H., Zou, Z., Shi, Z.L. and Jin, M. (2020) A serological survey of SARS-CoV-2 in cat in Wuhan. *Emerg. Microbes Infect.*, 9(1): 2013-2019.
28. Patterson, E.I., Elia, G., Grassi, A., Giordano, A., Desario, C., Medardo, M., Smith, S.L., Anderson, E.R., Prince, T., Patterson, G.T., Lorusso, E., Lucente, M.S., Lanave, G., Lauzi, S., Bonfanti, U., Stranieri, A., Martella, V., Solari-Basano, F., Barrs, V.R., Radford, A.D., Agrimi U., Hughes G.L., Paltrinieri S. and Decaro, N. (2020) Evidence of exposure to SARS-CoV-2 in cats and dogs from households in Italy. *Nat. Commun.*, 11(1): 6231.
29. McAloose, D., Laverack, M., Wang, L., Killian, M.L., Caserta, L.C., Yuan, F., Mitchell, P.K., Queen, K., Mauldin, M.R., Cronk, B.D., Bartlett, S.L., Sykes, J.M., Zec, S., Stokol, T., Ingerman, K., Delaney, M.A., Fredrickson, R., Ivančić, M., Jenkins-Moore, M., Mzingo, K., Franzen, K., Bergeson, N.H., Goodman, L., Wang, H., Fang, Y., Olmstead, C., McCann, C., Thomas, P., Goodrich, E., Elvinger, F., Smith, D.C., Tong, S., Slavinski, S., Calle, P.P., Terio, K., Torchetti, M.K. and Diel, D.G. (2020) From people to *Panthera*: Natural SARS-CoV-2 infection in tigers and lions at the Bronx Zoo. *mBio*, 11(5): e02220-20.
30. Bartlett, S.L., Diel, D.G., Wang, L., Zec, S., Laverack, M., Martins, M., Caserta, L.C., Killian, M.L., Terio, K., Olmstead, C., Delaney, M.A., Stokol, T., Ivančić, M., Jenkins-Moore, M., Ingerman, K., Teegan, T., McCann, C., Thomas, P., McAloose, D., Sykes, J.M. and Calle, P.P. (2021) SARS-COV-2 infection and longitudinal fecal screening in Malayan tigers (*Panthera tigris jacksoni*), amur tigers (*Panthera tigris altaica*), and African lions (*Panthera leo krugeri*) at the bronx zoo, New York, USA. *J. Zoo Wildl. Med.*, 51(4): 733-744.
31. Chandler, J.C., Bevins, S.N., Ellis, J.W., Linder, T.J., Tell, R.M., Jenkins-Moore, M., Root, J.J., Lenocho, J.B., Robbe-Austerman, S., DeLiberto, T.J., Gidlewski, T.,

- Torchetti, M.K. and Shriner, S.A. (2021) SARS-CoV-2 exposure in wild white-tailed deer (*Odocoileus virginianus*). *Proc. Natl. Acad. Sci.*, 118(47): e2114828118.
32. Ahmed, W., Angel, N., Edson, J., Bibby, K., Bivins, A., O'Brien, J.W., Choi, P.M., Kitajima, M., Simpson, S.L., Li, J., Tscharke, B., Verhagen, R., Smith, W., Zaugg, J., Dierens, L., Hugenholtz, P., Thomas, K.V. and Mueller, J.F. (2020) First confirmed detection of SARS-CoV-2 in untreated wastewater in Australia: A proof of concept for the wastewater surveillance of COVID-19 in the community. *Sci. Total Environ.*, 728: 138764.
  33. Smyth, D.S., Trujillo, M., Gregory, D.A., Cheung, K., Gao, A., Graham, M., Guan, Y., Guldenpfennig, C., Hoxie, I., Kannoly, S., Kubota, N., Lyddon, T.D., Markman, M., Rushford, C., San, K.M., Sompanya, G., Spagnolo, F., Suarez, R., Teixeira, E., Daniels, M., Johnson, M.C. and Dennehy, J.J. (2022) Tracking cryptic SARS-CoV-2 lineages detected in NYC wastewater. *Nat. Commun.*, 13(1): 635.
  34. Oreshkova, N., Molenaar, R.J., Vreman, S., Harders, F., Oude Munnink, B.B., Hakze-van der Honing, R.W., Gerhards, N., Tolsma, P., Bouwstra, R., Sikkema, R.S., Tacken, M.G., de Rooij, M.M., Weesendorp, E., Engelsma, M.Y., Brusckke, C.J., Smit, L.A., Koopmans, M., van der Poel, W.H. and Stegeman, A. (2020) SARS-CoV-2 infection in farmed minks, the Netherlands, April and May 2020. *Eurosurveillance*, 25(23): 2001005.
  35. Munnink, B.B., Sikkema, R.S., Nieuwenhuijse, D.F., Molenaar, R.J., Munger, E., Molenkamp, R., van der Spek, A., Tolsma, P., Rietveld, A., Brouwer, M., Bouwmeester-Vincken, N., Harders, F., Hakze-van der Honing, R., Wegdam-Blans, M., Bouwstra, R.J., GeurtsvanKessel, C., van der Eijk, A.A., Velkers, F.C., Smit, L., Stegeman, A., van der Poel W.H.M. and Koopmans, M. (2021) Transmission of SARS-CoV-2 on mink farms between humans and mink and back to humans. *Science*, 371(6525): 172-177.
  36. Halfmann, P.J., Hatta, M., Chiba, S., Maemura, T., Fan, S., Takeda, M., Kinoshita, N., Hattori, S.I., Sakai-Tagawa, Y., Iwatsuki-Horimoto, K., Imai, M. and Kawaoka, Y. (2020) Transmission of SARS-CoV-2 in domestic cats. *N. Engl. J. Med.*, 383(6): 592-594.
  37. Bosco-Lauth, A.M., Hartwig, A.E., Porter, S.M., Gordy, P.W., Nehring, M., Byas, A.D., Vande-Woude, S., Ragan, I.K., Maison, R.M. and Bowen, R.A. (2020) Experimental infection of domestic dogs and cats with SARS-CoV-2: Pathogenesis, transmission, and response to reexposure in cats. *Proc. Natl. Acad. Sci.*, 117(42): 26382-26388.
  38. Chiba, S., Halfmann, P.J., Hatta, M., Maemura, T., Fan, S., Armbrust, T., Swartley, O.M., Crawford, L.K. and Kawaoka, Y. (2021) protective immunity and persistent lung sequelae in domestic cats after SARS-CoV-2 infection. *Emerg. Infect. Dis.*, 27(2): 660-663.
  39. Gaudreault, N.N., Trujillo, J.D., Carossino, M., Meekins, D.A., Morozov, I., Madden, D.W., Indran, S.V., Bold, D., Balaraman, V., Kwon, T., Artiaga, B.L., Cool, K., García-Sastre, A., Ma, W., Wilson, W.C., Henningson, J., Balasuriya, U. and Richt, J.A. (2020) SARS-CoV-2 infection, disease and transmission in domestic cats. *Emerg. Microbes Infect.*, 9(1): 2322-2332.
  40. Falkenberg, S., Buckley, A., Laverack, M., Martins, M., Palmer, M.V., Lager, K. and Diel, D.G. (2021) Experimental inoculation of young calves with SARS-CoV-2. *Viruses*, 13(3): 441.
  41. Di Teodoro, G., Valleriani, F., Puglia, I., Monaco, F., Di Pancrazio, C., Luciani, M., Krasteva, I., Petrini, A., Marcacci, M., D'Alterio, N., Curini, V., Iorio, M., Migliorati, G., Di Domenico, M., Morelli, D., Calistri, P., Savini, G., Decaro, N., Holmes, E.C. and Lorusso, A. (2021) SARS-CoV-2 replicates in respiratory *ex vivo* organ cultures of domestic ruminant species. *Vet. Microbiol.*, 252: 108933.
  42. Ulrich, L., Wernike, K., Hoffmann, D., Mettenleiter, T.C. and Beer, M. (2020) Experimental infection of cattle with SARS-CoV-2. *Emerg. Infect. Dis.*, 26(12): 2979-2981.
  43. Palmer, M.V., Martins, M., Falkenberg, S., Buckley, A., Caserta, L.C., Mitchell, P.K., Cassman, E.D., Rollins, A., Zyllich, N.C., Renshaw, R.W., Guarino, C., Wagner, B., Lager, K. and Diel, D.G. (2021) Susceptibility of white-tailed deer (*Odocoileus virginianus*) to SARS-CoV-2. *J. Virol.*, 95(11): e00083-21.
  44. Cool, K., Gaudreault, N. N., Morozov, I., Trujillo, J.D., Meekins, D.A., McDowell, C., Carossino, M., Bold, D., Kwon, T., Balaraman, V., Madden, D.W., Artiaga, B.L., Pogranichniy, R.M., Sosa, G.R., Henningson, J., Wilson, W.C., Balasuriya, U., García-Sastre, A. and Richt, J.A. (2021) Infection and transmission of SARS-CoV-2 and its alpha variant in pregnant white-tailed deer. *Emerg. Microbes Infect.*, 11(1): 95-112.
  45. Schlottau, K., Rissmann, M., Graaf, A., Schön, J., Sehl, J., Wylezich, C., Höper, D., Mettenleiter, T.C., Balkema-Buschmann, A., Harder, T., Grund, C., Hoffmann, D., Breithaupt, A. and Beer, M. (2020) SARS-CoV-2 in fruit bats, ferrets, pigs, and chickens: An experimental transmission study. *Lancet Microbe*, 1(5): e218-e225.
  46. Meekins, D.A., Morozov, I., Trujillo, J.D., Gaudreault, N.N., Bold, D., Carossino, M., Artiaga, B.L., Indran, S.V., Kwon, T., Balaraman, V., Madden, D.W., Feldmann, H., Henningson, J., Ma, W., Balasuriya, U. and Richt, J.A. (2020) Susceptibility of swine cells and domestic pigs to SARS-CoV-2. *Emerg. Microbes Infect.*, 9(1): 2278-2288.
  47. Vergara-Alert, J., Rodon, J., Carrillo, J., Te, N., Izquierdo-Useros, N., Rodríguez de la Concepción, M.L., Ávila-Nieto, C., Guallar, V., Valencia, A., Cantero, G., Blanco, J., Clotet, B., Bensaid, A. and Segalés, J. (2021) Pigs are not susceptible to SARS-CoV-2 infection but are a model for viral immunogenicity studies. *Transbound. Emerg. Dis.*, 68(4): 1721-1725.
  48. Pickering, B.S., Smith, G., Pinette, M.M., Embury-Hyatt, C., Moffat, E., Marszal, P. and Lewis, C.E. (2021) Susceptibility of domestic swine to experimental infection with severe acute respiratory syndrome coronavirus 2. *Emerg. Infect. Dis.*, 27(1): 104-112.
  49. Buckley, A., Falkenberg, S., Martins, M., Laverack, M., Palmer, M.V., Lager, K. and Diel, D.G. (2021) Intravenous, intratracheal, and intranasal inoculation of swine with SARS-CoV-2. *Viruses*, 13(8): 1506.
  50. Suarez, D.L., Pantin-Jackwood, M.J., Swayne, D.E., Lee, S.A., DeBlois, S.M. and Spackman, E. (2020) Lack of susceptibility to SARS-CoV-2 and MERS-CoV in poultry. *Emerg. Infect. Dis.*, 26(12): 3074-3076.
  51. Newman, A., Smith, D., Ghai, R.R., Wallace, R.M., Torchetti, M.K., Loiacono, C., Murrell, L.S., Carpenter, A., Moroff, S., Rooney, J.A. and Behravesh, C.B. (2020) First reported cases of SARS-CoV-2 infection in companion animals New York, March-April 2020. *MMWR Morb. Mortal. Wkly. Rep.*, 69(23): 710-713.
  52. Ruiz-Arrondo, I., Portillo, A., Palomar, A.M., Santibáñez, S., Santibáñez, P., Cervera, C. and Oteo, J.A. (2021) Detection of SARS-CoV-2 in pets living with COVID-19 owners diagnosed during the COVID-19 lockdown in Spain: A case of an asymptomatic cat with SARS-CoV-2 in Europe. *Transbound. Emerg. Dis.*, 68(2): 973-976.
  53. Segalés, J., Puig, M., Rodon, J., Avila-Nieto, C., Carrillo, J., Cantero, G., Terrón, M.T., Cruz, S., Parera, M., Noguera-Julian, M., Izquierdo-Useros, N., Guallar, V., Vidal, E., Valencia, A., Blanco, I., Blanco, J., Clotet, B. and Vergara-Alert, J. (2020) Detection of SARS-CoV-2 in a cat owned by a COVID-19-affected patient in Spain. *Proc. Natl. Acad. Sci.*, 117(40): 24790-24793.
  54. Dias, H.G., Resck, M., Caldas, G.C., Resck, A.F., da Silva, N.V., Dos Santos, A., Sousa, T., Ogrzewalska, M.H., Siqueira, M.M., Pauvolid-Corrêa, A. and Dos Santos, F.B. (2021) Neutralizing antibodies for SARS-CoV-2 in gray

- animals from Rio de Janeiro, Brazil. *PLoS One*, 16(3): e0248578.
55. Calvet, G.A., Pereira, S.A., Ogrzewalska, M., Pauvolid-Corrêa, A., Resende, P.C., Tassinari, W.S., Costa, A.P., Keidel, L.O., da Rocha, A., da Silva, M., Dos Santos, S.A., Lima, A., de Moraes, I., Mendes Junior, A., Souza, T., Martins, E.B., Ornellas, R.O., Corrêa, M.L., Antonio, I., Guaraldo, L., Motta F.D.C., Brasil, P., Siqueira, M.M., Gremião, I.D.F. and Menezes, R.C. (2021) Investigation of SARS-CoV-2 infection in dogs and cats of humans diagnosed with COVID-19 in Rio de Janeiro, Brazil. *PLoS One*, 16(4): e0250853.
  56. Molenaar, R.J., Vreman, S., Hakze-van der Honing, R.W., Zwart, R., de Rond, J., Weesendorp, E., Smit, L., Koopmans, M., Bouwstra, R., Stegeman, A. and van der Poel, W. (2020) Clinical and pathological findings in SARS-CoV-2 disease outbreaks in farmed mink (*Neovison vison*). *Vet. Pathol.*, 57(5): 653-657.
  57. Larsen, H.D., Fonager, J., Lomholt, F.K., Dalby, T., Benedetti, G., Kristensen, B., Urth, T.R., Rasmussen, M., Lassaunière, R., Rasmussen, T.B., Strandbygaard, B., Lohse, L., Chaine, M., Møller, K.L., Berthelsen, A.N., Nørgaard, S.K., Sønksen, U.W., Boklund, A.E., Hammer, A.S., Belsham, G.J., Krause, T.G., Mortensen, S., Bøtner, A., Fomsgaard, A. and Mølbak, K. (2021). Preliminary report of an outbreak of SARS-CoV-2 in mink and mink farmers associated with community spread, Denmark, June to November 2020. *Eurosurveillance*, 26(5): 2100009.
  58. Domańska-Blicharz, K., Orłowska, A., Smreczak, M., Niemczuk, K., Iwan, E., Bomba, A., Lisowska, A., Opolska, J., Trębas, P., Potyrało, P., Kawiak-Sadurska, M. and Rola, J. (2021) Mink SARS-CoV-2 infection in Poland short communication. *J. Vet. Res.*, 65(1): 1-5.
  59. APHIS USDA. (2021) Confirmation of COVID-19 in a Cougar at a Wild Animal Exhibitor in Texas. Available from: [https://www.aphis.usda.gov/aphis/newsroom/stakeholder-info/sa\\_by\\_date/sa-2021/sa-02/sars-cov-2-texas-cougar](https://www.aphis.usda.gov/aphis/newsroom/stakeholder-info/sa_by_date/sa-2021/sa-02/sars-cov-2-texas-cougar) Retrieved 21-09-2021.
  60. Trent, R. (2021) A Rare Snow Leopard at the San Diego Zoo has Tested Positive for Coronavirus. Updated 0300 GMT (1100 HKT) July 26, 2021. Available from: <https://edition.cnn.com/2021/07/25/us/snow-leopard-coronavirus-san-diego-trnd/index.html> Retrieved 21-09-2021.
  61. Andrew, S. (2020) Three Snow Leopards Test Positive for Coronavirus, Making it the Sixth Confirmed Animal Species. Updated 2112 GMT (0512 HKT). Available from: <https://edition.cnn.com/2020/12/11/us/snow-leopard-positive-coronavirus-kentucky-zoo-trnd/index.html> Retrieved 21-09-2021.
  62. Mishra, A., Kumar, N., Bhatia, S., Aasdev, A., Kanniappan, S., Thayasekhar, A., Gopinadhan, A., Silambarasan, R., Sreekumar, C., Dubey, C.K., Tripathi, M., Raut, A.A. and Singh, V.P. (2021) SARS-CoV-2 delta variant among Asiatic lions, India. *Emerg. Infect. Dis.*, 27(10): 2723-2725.
  63. Karikalan, M., Chander, V., Mahajan, S., Deol, P., Agrawal, R.K., Nandi, S., Rai, S.K., Mathur, A., Pawde, A., Singh, K.P. and Sharma, G.K. (2021) Natural infection of delta mutant of SARS-CoV-2 in Asiatic lions of India. *Transbound. Emerg. Dis.*, 10.1111/tbed.14290.
  64. Fernández-Bellon, H., Rodon, J., Fernández-Bastit, L., Almagro, V., Padilla-Solé, P., Lorca-Oró, C., Valle, R., Roca, N., Grazioli, S., Trogu, T., Bensaid, A., Carrillo, J., Izquierdo-Useros, N., Blanco, J., Parera, M., Noguera-Julián, M., Clotet, B., Moreno, A., Segalés, J. and Vergara-Alert, J. (2021) Monitoring natural SARS-CoV-2 infection in lions (*Panthera leo*) at the Barcelona zoo: Viral dynamics and host responses. *Viruses*, 13(9): 1683.
  65. CNN Indonesia. (2021a) 2 Harimau Sumatra di Ragunan Positif Covid-19. CNN Indonesia. Minggu, 01/08/2021 09:17 WIB. Available from: <https://www.cnnindonesia.com/nasional/20210801090321-20-674809/2-harimau-sumatra-di-ragunan-positif-covid-19> Retrieved on 30-08-2021.
  66. CNN Indonesia. (2021b) Kronologi Harimau Ragunan “Tino dan Hari” Terinfeksi Covid-19. Minggu, 01/08/2021 12:39 WIB. Available from: <https://www.cnnindonesia.com/nasional/20210801123251-20-674876/kronologi-harimau-ragunan-tino-dan-hari-terinfeksi-covid-19> Retrieved on 30-08-2021.
  67. OIE. (2020) Follow-up Report No. 2. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/reviewreport/review?reportid=34086](https://www.oie.int/wahis_2/public/wahid.php/reviewreport/review?reportid=34086) Retrieved on 13-10-2020.
  68. OIE. (2020) Follow-up report No. 3. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/reviewreport/review?reportid=34169](https://www.oie.int/wahis_2/public/wahid.php/reviewreport/review?reportid=34169) Retrieved on 13-10-2020.
  69. OIE. (2020) Follow-up Report No. 17. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/reviewreport/review?reportid=35605](https://www.oie.int/wahis_2/public/wahid.php/reviewreport/review?reportid=35605) Retrieved on 13-10-2020.
  70. OIE. (2020) Follow-up Report No. 18. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/reviewreport/review?reportid=35691](https://www.oie.int/wahis_2/public/wahid.php/reviewreport/review?reportid=35691) Retrieved on 13-10-2020.
  71. OIE. (2020) Follow-up Report No. 19. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/reviewreport/review?reportid=35857](https://www.oie.int/wahis_2/public/wahid.php/reviewreport/review?reportid=35857) Retrieved on 13-10-2020.
  72. OIE. (2020) Follow-up Report No. 20. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/reviewreport/review?reportid=35946](https://www.oie.int/wahis_2/public/wahid.php/reviewreport/review?reportid=35946) Retrieved on 13-10-2020.
  73. OIE. (2020) Follow-up Report No. 21. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/reviewreport/review?reportid=35973](https://www.oie.int/wahis_2/public/wahid.php/reviewreport/review?reportid=35973) Retrieved on 13-10-2020.
  74. OIE. (2020) Follow-up Report No. 23. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/reviewreport/review?reportid=36309](https://www.oie.int/wahis_2/public/wahid.php/reviewreport/review?reportid=36309) Retrieved on 13-10-2020.
  75. OIE. (2020) Follow-up Report No. 5. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/reviewreport/review?reportid=34548](https://www.oie.int/wahis_2/public/wahid.php/reviewreport/review?reportid=34548) Retrieved on 13-10-2020.
  76. OIE. (2020) Follow-up Report No. 6. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/reviewreport/review?reportid=34590](https://www.oie.int/wahis_2/public/wahid.php/reviewreport/review?reportid=34590) Retrieved on 13-10-2020.
  77. OIE. (2020) Follow-up Report No. 7. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/reviewreport/review?reportid=34824](https://www.oie.int/wahis_2/public/wahid.php/reviewreport/review?reportid=34824) Retrieved on 13-10-2020.
  78. OIE. (2020) Follow-up Report No. 9. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/reviewreport/review?reportid=34991](https://www.oie.int/wahis_2/public/wahid.php/reviewreport/review?reportid=34991) Retrieved on 13-10-2020.
  79. OIE. (2020) Follow-up Report No. 11. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/reviewreport/review?reportid=35140](https://www.oie.int/wahis_2/public/wahid.php/reviewreport/review?reportid=35140) Retrieved on 13-10-2020.
  80. OIE. (2020) Follow-up Report No. 12. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/reviewreport/review?reportid=35236](https://www.oie.int/wahis_2/public/wahid.php/reviewreport/review?reportid=35236) Retrieved on 13-10-2020.
  81. OIE. (2020) Follow-up Report No. 14. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/reviewreport/review?reportid=35408](https://www.oie.int/wahis_2/public/wahid.php/reviewreport/review?reportid=35408) Retrieved on 13-10-2020.
  82. OIE. (2020) Follow-up Report No. 16. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/reviewreport/review?reportid=35525](https://www.oie.int/wahis_2/public/wahid.php/reviewreport/review?reportid=35525) Retrieved on 13-10-2020.
  83. OIE. (2020) Follow-up Report No. 8. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/Reviewreport/review?reportid=34937](https://www.oie.int/wahis_2/public/wahid.php/Reviewreport/review?reportid=34937) Retrieved on 13-10-2020.
  84. OIE. (2020) Follow-up Report No. 10. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/reviewreport/review?reportid=35051](https://www.oie.int/wahis_2/public/wahid.php/reviewreport/review?reportid=35051) Retrieved on 13-10-2020.
  85. OIE. (2020) Follow-up Report No. 13. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/reviewreport/review?reportid=35306](https://www.oie.int/wahis_2/public/wahid.php/reviewreport/review?reportid=35306) Retrieved on 13-10-2020.
  86. OIE. (2020) Follow-up Report No. 4. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/reviewreport/review?reportid=34525](https://www.oie.int/wahis_2/public/wahid.php/reviewreport/review?reportid=34525) Retrieved on 13-10-2020.
  87. OIE. (2020) Follow-up Report No. 15. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/reviewreport/review?reportid=35412](https://www.oie.int/wahis_2/public/wahid.php/reviewreport/review?reportid=35412) Retrieved on 13-10-2020.

88. OIE. (2020) Follow-up Report No. 22. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/reviewreport/review?reportid=36151](https://www.oie.int/wahis_2/public/wahid.php/reviewreport/review?reportid=36151) Retrieved on 13-10-2020.
89. OIE. (2020) Follow-up Report No. 25. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/reviewreport/review?reportid=36580](https://www.oie.int/wahis_2/public/wahid.php/reviewreport/review?reportid=36580) Retrieved on 15-12-2020.
90. OIE. (2020) Follow-up Report No. 26. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/reviewreport/review?reportid=36731](https://www.oie.int/wahis_2/public/wahid.php/reviewreport/review?reportid=36731) Retrieved on 13-10-2020.
91. Holcombe, M. and Mossburg, C. (2021) San Diego Zoo gorillas make full recovery from Covid-19. Updated 1336 GMT (2136 HKT) February 16, 2021. Available from: <https://edition.cnn.com/2021/02/16/us/san-diego-zoo-covid-19-gorilla-recovery-trnd/index.html> Retrieved on 21-09-2021.
92. Udom, K., Jairak, W., Chamsai, E., Charoenkul, K., Boonyapisitsopa, S., Bunpapong, N., Techakriengkrai, N. and Amonsin, A. (2021) Serological survey of antibodies against SARS-CoV-2 in dogs and cats, Thailand. *Transbound. Emerg. Dis.*, 10.1111/tbed.14208.
93. Fritz, M., Rosolen, B., Krafft, E., Becquart, P., Elguero, E., Vraskikh, O., Denolly, S., Boson, B., Vanhomwegen, J., Gouilh, M.A., Kodjo, A., Chirouze, C., Rosolen, S.G., Legros, V. and Leroy, E.M. (2020) High prevalence of SARS-CoV-2 antibodies in pets from COVID-19+ households. *One Health*, 11: 100192.
94. Hamer, S.A., Pauvolid-Corrêa, A., Zecca, I.B., Davila, E., Auckland, L.D., Roundy, C.M., Tang, W., Torchetti, M.K., Killian, M.L., Jenkins-Moore, M., Mozingo, K., Akpalu, Y., Ghai, R.R., Spengler, J.R., Barton Behravesh, C., Fischer, R. and Hamer, G.L. (2021) SARS-CoV-2 Infections and viral isolations among serially tested cats and dogs in households with infected owners in Texas, USA. *Viruses*, 13(5): 938.
95. Zhai, X., Sun, J., Yan, Z., Zhang, J., Zhao, J., Zhao, Z., Gao, Q., He, W.T., Veit, M. and Su, S. (2020) Comparison of severe acute respiratory syndrome coronavirus 2 spike protein binding to ACE2 receptors from human, pets, farm animals, and putative intermediate hosts. *J. Virol.*, 94(15): e00831-20.
96. Giraldo-Ramirez, S., Rendon-Marin, S., Jaimes, J.A., Martinez-Gutierrez, M. and Ruiz-Saenz, J. (2021) SARS-CoV-2 clinical outcome in domestic and wild cats: A systematic review. *Animals*, 11(7): 2056.
97. Ferasin, L., Fritz, M., Ferasin, H., Becquart, P., Corbet, S., Ar Gouilh, M., Legros, V. and Leroy, E.M. (2021) Infection with SARS-CoV-2 variant B.1.1.7 detected in a group of dogs and cats with suspected myocarditis. *Vet. Rec.*, 189(9): e944.
98. Zhao, Y., Yang, Y., Gao, J., Huang, K., Hu, C., Hui, X., He, X., Li, C., Gong, W., Lv, C., Zhang, Y., Chen, H., Zou, Z., Zhang, Q. and Jin, M. (2021) A serological survey of severe acute respiratory syndrome coronavirus 2 in dogs in Wuhan. *Transbound. Emerg. Dis.*, 10.1111/tbed.14024.
99. Stevanovic, V., Tabain, I., Vilibic-Cavlek, T., Mauric Maljkovic, M., Benvin, I., Hruskar, Z., Kovac, S., Smit, I., Miletic, G., Hadina, S., Staresina, V., Radin, L., Plichta, V., Skrlin, B., Vrbanac, Z., Brkljacic, M., Cvetnic, M., Habus, J., Martinkovic, K., Zecevic, I., Jurkic, G., Ferencak, I., Stritof, Z., Perharic, M., Bucic, L. and Barbic, L. (2021) The emergence of SARS-CoV-2 within the dog population in Croatia: Host factors and clinical outcome. *Viruses*, 13(8): 1430.
100. Smith, S.L., Anderson, E.R., Cansado-Utrilla, C., Prince, T., Farrell, S., Brant, B., Smyth, S., Noble, P.M., Pinchbeck, G.L., Marshall, N., Roberts, L., Hughes, G.L., Radford, A.D. and Patterson, E.I. (2021) SARS-CoV-2 neutralising antibodies in dogs and cats in the United Kingdom. *Curr. Res. Virol. Sci.*, 2: 100011.
101. APHIS USDA. (2020) Confirmation of COVID-19 in Pet Dog in New York. Animal and Plant Health Inspection Service (APHIS), U.S. Department of Agriculture (USDA). Available from: [https://www.aphis.usda.gov/aphis/newsroom/stakeholder-info/sa\\_by\\_date/sa-2020/sa-06/sars-cov-2-dog](https://www.aphis.usda.gov/aphis/newsroom/stakeholder-info/sa_by_date/sa-2020/sa-06/sars-cov-2-dog) Retrieved on 05-11-2020.
102. Dileepan, M., Di, D., Huang, Q., Ahmed, S., Heinrich, D., Ly, H. and Liang, Y. (2021) Seroprevalence of SARS-CoV-2 (COVID-19) exposure in pet cats and dogs in Minnesota, USA. *Virulence*, 12(1): 1597-1609.
103. Mathavarajah, S. and Dellaire, G. (2020) Lions, tigers and kittens too: ACE2 and susceptibility to COVID-19. *Evol. Med. Public Health*, 2020(1): 109-113.
104. OIE. (2020) Immediate Case. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/reviewreport/review?reportid=33885](https://www.oie.int/wahis_2/public/wahid.php/reviewreport/review?reportid=33885) Retrieved on 13-10-2020.
105. OIE. (2020) Follow-up Report No. 1. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/reviewreport/review?reportid=34054](https://www.oie.int/wahis_2/public/wahid.php/reviewreport/review?reportid=34054) Retrieved on 13-10-2020.
106. OIE. (2020) Follow-up Report No. 24. Available from: [https://www.oie.int/wahis\\_2/public/wahid.php/reviewreport/review?reportid=36433](https://www.oie.int/wahis_2/public/wahid.php/reviewreport/review?reportid=36433) Retrieved on 15-12-2020.
107. Smithsonian's National Zoo and Conservation Biology Institute. (2021) Great Cats Tested Presumptive Positive for COVID-19 at the Smithsonian's National Zoo. Available from: <https://nationalzoo.si.edu/news/great-cats-tested-presumptive-positive-for-covid-19-smithsonians-national-zoo> Retrieved on 25-09-2021.
108. Damas, J., Hughes, G.M., Keough, K.C., Painter, C.A., Persky, N.S., Corbo, M., Hiller, M., Koepfli, K.P., Pfenning, A.R., Zhao, H., Genereux, D.P., Swofford, R., Pollard, K.S., Ryder, O.A., Nweeia, M.T., Lindblad-Toh, K., Teeling, E.C., Karlsson, E.K. and Lewin, H.A. (2020) Broad host range of SARS-CoV-2 predicted by comparative and structural analysis of ACE2 in vertebrates. *Proc. Natl. Acad. Sci.*, 117(36): 22311-22322.
109. Lean, F., Núñez, A., Spiro, S., Priestnall, S.L., Vreman, S., Bailey, D., James, J., Wrigglesworth, E., Suarez-Bonnet, A., Conceicao, C., Thakur, N., Byrne, A., Ackroyd, S., Delahay, R.J., van der Poel, W., Brown, I.H., Fooks, A.R. and Brookes, S.M. (2021) Differential susceptibility of SARS-CoV-2 in animals: Evidence of ACE2 host receptor distribution in companion animals, livestock and wildlife by immunohistochemical characterisation. *Transbound. Emerg. Dis.*, 10.1111/tbed.14232.
110. APHIS USDA. (2021) Confirmation of COVID-19 in Deer in Ohio. Available from: [https://www.aphis.usda.gov/aphis/newsroom/stakeholder-info/sa\\_by\\_date/sa-2021/sa-08/covid-deer](https://www.aphis.usda.gov/aphis/newsroom/stakeholder-info/sa_by_date/sa-2021/sa-08/covid-deer) Retrieved on 2021-09-25.
111. Hammer, A.S., Quaade, M.L., Rasmussen, T.B., Fonager, J., Rasmussen, M., Mundbjerg, K., Lohse, L., Strandbygaard, B., Jørgensen, C.S., Alfaro-Núñez, A., Rosenstjerne, M.W., Boklund, A., Halasa, T., Fomsgaard, A., Belsham, G.J. and Bøtner, A. (2021) SARS-CoV-2 transmission between mink (*Neovison vison*) and Humans, Denmark. *Emerg. Infect. Dis.*, 27(2): 547-551.
112. Boklund, A., Hammer, A.S., Quaade, M.L., Rasmussen, T.B., Lohse, L., Strandbygaard, B., Jørgensen, C.S., Olesen, A.S., Hjerpe, F.B., Petersen, H.H., Jensen, T.K., Mortensen, S., Calvo-Artavia, F.F., Lefèvre, S.K., Nielsen, S.S., Halasa, T., Belsham, G.J. and Bøtner, A. (2021) SARS-CoV-2 in Danish mink farms: Course of the epidemic and a descriptive analysis of the outbreaks in 2020. *Animals*, 11(1): 164.
113. Rabalski, L., Kosinski, M., Smura, T., Aaltonen, K., Kant, R., Sironen, T., Szewczyk, B. and Grzybek, M. (2021) Severe acute respiratory syndrome coronavirus 2 in farmed mink (*Neovison vison*), Poland. *Emerg. Infect. Dis.*, 27(9): 2333-2339.
114. Rasmussen, T.B., Fonager, J., Jørgensen, C.S., Lassaunière, R., Hammer, A.S., Quaade, M.L., Boklund, A., Lohse, L., Strandbygaard, B., Rasmussen, M., Michaelsen, T.Y., Mortensen, S., Fomsgaard, A., Belsham, G.J. and Bøtner, A. (2021) Infection, recovery and re-infection of farmed mink with SARS-CoV-2. *PLoS Pathog.*, 17(11): e1010068.

115. Rabalski, L., Kosinski, M., Mazur-Panasiuk, N., Szewczyk, B., Bienkowska-Szewczyk, K., Kant, R., Sironen, T., Pyrc, K. and Grzybek, M. (2021) Zoonotic spillover of SARS-CoV-2: Mink-adapted virus in humans. *Clin. Microbiol. Infect.*, S1198-743X(21): 00698-4.
116. Hoffmann, M., Zhang, L., Krüger, N., Graichen, L., Kleine-Weber, H., Hofmann-Winkler, H., Kempf, A., Nessler, S., Riggert, J., Winkler, M.S., Schulz, S., Jäck, H.M. and Pöhlmann, S. (2021) SARS-CoV-2 mutations acquired in mink reduce antibody-mediated neutralization. *Cell Rep.*, 35(3): 109017.
117. Asadi, S., Bouvier, N., Wexler, A.S. and Ristenpart, W.D. (2020) The coronavirus pandemic and aerosols: Does COVID-19 transmit via expiratory particles? *Aerosol Sci. Technol.*, 54(6): 635-638.
118. Zhao, J., Cui, W. and Tian, B.P. (2020) The potential intermediate hosts for SARS-CoV-2. *Front. Microbiol.*, 11: 580137.
119. van Aart, A.E., Velkers, F.C., Fischer, E., Broens, E.M., Egberink, H., Zhao, S., Engelsma, M., Hakze-van der Honing, R.W., Harders, F., de Rooij, M., Radstake, C., Meijer, P.A., Oude Munnink, B.B., de Rond, J., Sikkema, R.S., van der Spek, A.N., Spierenburg, M., Wolters, W.J., Molenaar, R.J., Koopmans, M., van der Poel, W.H.M., Stegeman, A. and Smit, L. (2021) SARS-CoV-2 infection in cats and dogs in infected mink farms. *Transbound. Emerg. Dis.*, 10.1111/tbed.14173.
120. APHIS USDA. (2021) Confirmation of COVID-19 in Otters at an Aquarium in Georgia. Available from: [https://www.aphis.usda.gov/aphis/newsroom/stakeholder-info/sa\\_by\\_date/sa-2021/sa-04/covid-georgia-otters](https://www.aphis.usda.gov/aphis/newsroom/stakeholder-info/sa_by_date/sa-2021/sa-04/covid-georgia-otters) Retrieved on 21-09-2021.
121. APHIS USDA. (2021) Confirmation of COVID-19 in a Binturong and a Fishing Cat at an Illinois Zoo. Available from: [https://www.aphis.usda.gov/aphis/newsroom/stakeholder-info/sa\\_by\\_date/sa-2021/sa-10/covid-binturong-fishing-cat](https://www.aphis.usda.gov/aphis/newsroom/stakeholder-info/sa_by_date/sa-2021/sa-10/covid-binturong-fishing-cat) Retrieved on 09-01-2022.
122. APHIS USDA. (2021) Confirmation of COVID-19 in a Coatimundi at an Illinois Zoo. Available from: [https://www.aphis.usda.gov/aphis/newsroom/stakeholder-info/sa\\_by\\_date/sa-2021/sa-10/covid-coatimundi](https://www.aphis.usda.gov/aphis/newsroom/stakeholder-info/sa_by_date/sa-2021/sa-10/covid-coatimundi) Retrieved on 09-01-2022.
123. APHIS USDA. (2021) Confirmation of COVID-19 in Hyenas at a Colorado Zoo. Available from: [https://www.aphis.usda.gov/aphis/newsroom/stakeholder-info/sa\\_by\\_date/sa-2021/sa-11/covid-hyenas](https://www.aphis.usda.gov/aphis/newsroom/stakeholder-info/sa_by_date/sa-2021/sa-11/covid-hyenas) Retrieved on 09-01-2022.
124. Mawad, D. and Hu, C. (2021) Runny-nosed Hippos Test Positive for Covid-19 in Belgium. Updated 0231 GMT (1031 HKT) December 6, 2021. Available from: <https://edition.cnn.com/2021/12/05/americas/covid-19-hippos-belgium-intl/index.html> Retrieved on 09-01-2022.
125. Chavda, V.P., Feehan, J. and Apostolopoulos, V. (2021) A veterinary vaccine for SARS-CoV-2: The first COVID-19 vaccine for animals. *Vaccines*, 9(6): 631.
126. Baraniuk, C. (2021) The Rise of COVID-19 Vaccines for Animals. Available from: <https://www.the-scientist.com/news-opinion/the-rise-of-covid-19-vaccines-for-animals-69503> Retrieved on 15-01-2022.
127. Applied DNA Sciences. (2021) Applied DNA and Evvivax Announce Positive Preliminary Results of Phase I Clinical Trial for LinearDNA™ COVID-19 Vaccine Candidate in Felines. Available from: <https://adnas.com/feline-clinical-trial-preliminary-results> Retrieved on 15-01-2022.
128. Cornell University, Colleges of Veterinary Medicine. (2021) Safety and Immunogenicity of Linear COVID-19 DNA Vaccine, an Anti-SARS-CoV-2 Linear DNA Vaccine in Mink. Available from: <https://www.vet.cornell.edu/research/awards/202108/safety-and-immunogenicity-linear-covid-19-dna-vaccine-anti-sars-co-v-2-linear-dna-vaccine-mink> Retrieved on 15-01-2022.
129. Sharun, K., Tiwari, R., Saied, A.A. and Dhama, K. (2021) SARS-CoV-2 vaccine for domestic and captive animals: An effort to counter COVID-19 pandemic at the human-animal interface. *Vaccine*, 39(49): 7119-7122.

\*\*\*\*\*





# Source details

## Veterinary World

Open Access ⓘ

Scopus coverage years: from 2008 to Present

Publisher: Veterinary World

ISSN: 0972-8988 E-ISSN: 2231-0916

Subject area: Veterinary: General Veterinary

Source type: Journal

CiteScore 2021

3.0



SJR 2021

0.457



SNIP 2021

1.121



[View all documents >](#)

[Set document alert](#)

[Save to source list](#) [Source Homepage](#)

[CiteScore](#) [CiteScore rank & trend](#) [Scopus content coverage](#)

### i Improved CiteScore methodology



CiteScore 2021 counts the citations received in 2018-2021 to articles, reviews, conference papers, book chapters and data papers published in 2018-2021, and divides this by the number of publications published in 2018-2021. [Learn more >](#)

CiteScore 2021 ⌵

$$3.0 = \frac{4,053 \text{ Citations 2018 - 2021}}{1,358 \text{ Documents 2018 - 2021}}$$

Calculated on 05 May, 2022

CiteScoreTracker 2022 ⓘ

$$2.7 = \frac{3,540 \text{ Citations to date}}{1,328 \text{ Documents to date}}$$

Last updated on 05 September, 2022 • Updated monthly

## CiteScore rank 2021 ⓘ

Category	Rank	Percentile
Veterinary		
General Veterinary	#38/183	79th

[View CiteScore methodology >](#) [CiteScore FAQ >](#) [Add CiteScore to your site](#)



### Get started on Google Cloud

Start solving real world business challenges for your enterprise.

Google Cloud Sign Up

## Veterinary World

**COUNTRY**

[India](#)  


**SUBJECT AREA AND CATEGORY**

[Veterinary](#)  
[Veterinary \(miscellaneous\)](#)

**PUBLISHER**

[Veterinary World](#)

**H-INDEX**

**35**

**PUBLICATION TYPE**

Journals

**ISSN**

09728988, 22310916

**COVERAGE**

2008-2021

**INFORMATION**

[Homepage](#)  
[How to publish in this journal](#)  
[editorveterinaryworld@gmail.com](mailto:editorveterinaryworld@gmail.com)


← Ads by Google

Stop seeing this ad

Why this ad? 

**SCOPE**

Veterinary World publishes high quality papers focusing on Veterinary and Animal Science. The fields of study are bacteriology, parasitology, pathology, virology, immunology, mycology, public health, biotechnology, meat science, fish diseases, nutrition, gynecology, genetics, wildlife, laboratory animals, animal models of human infections, prion diseases and epidemiology. Studies on zoonotic and emerging infections are highly appreciated. Review articles are highly appreciated. All articles published by Veterinary World are made freely and permanently accessible online. All articles to Veterinary World are posted online immediately as they are ready for publication.

 Join the conversation about this journal



← Ads by Google

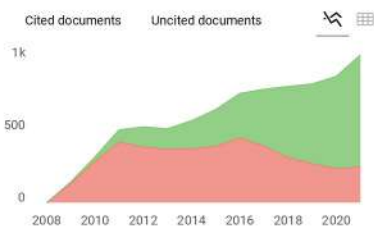
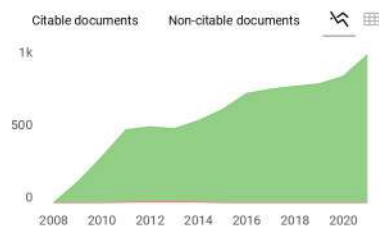
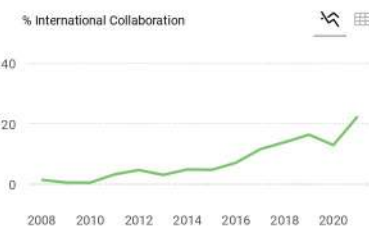
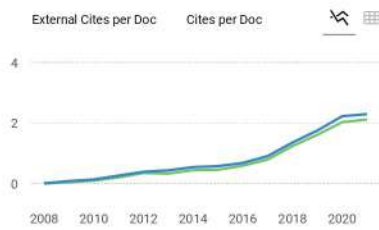
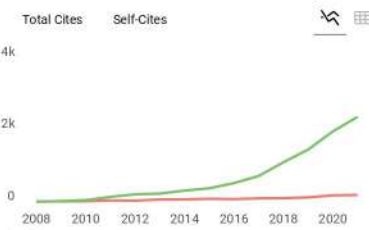
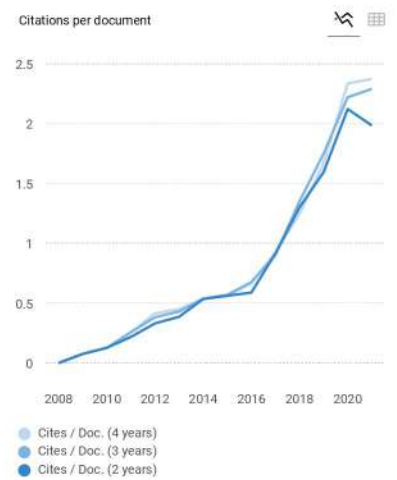
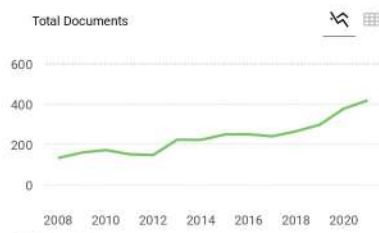
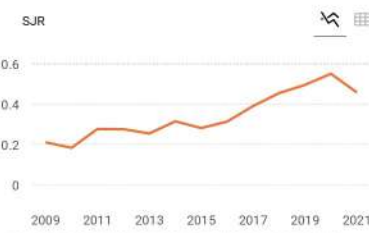
Stop seeing this ad Why this ad? 



FIND SIMILAR JOURNALS ⓘ

options ⋮

- 1 **Journal of Advanced Veterinary and Animal**  
BGD  
**67%**  
similarity
- 2 **Advances in Animal and Veterinary Sciences**  
PAK  
**63%**  
similarity
- 3 **Iraqi Journal of Veterinary Sciences**  
IRQ  
**62%**  
similarity
- 4 **Bulgarian Journal of Veterinary Medicine**  
BGR  
**60%**  
similarity
- 5 **Turkish Journal of Veterinary and Animal Sciences**  
TUR  
**57%**  
similarity



**Veterinary World** ← Show this widget in your own website

Veterinary (miscellaneous)  
best quartile

SJR 2021  
**0.46**

powered by scimagojr.com

Just copy the code below and paste within your html code:  
<a href="https://www.scimagojr.com" data-bbox="188 731 288 741">

**SCImago Graphica**

Explore, visually communicate and make sense of data with our **new data visualization tool.**

Published with Hindawi

Hindawi

Open



UNIVERSITAS AIRLANGGA  
FAKULTAS KEDOKTERAN

Kampus A Jl. Mayjen Prof. Dr. Moestopo 47 Surabaya 60131  
Telp. (031) 5020251, 5030252-3 Fax. (031) 5022472  
Laman : <http://www.fk.unair.ac.id> e-mail : [dekan@fk.unair.ac.id](mailto:dekan@fk.unair.ac.id)

**SURAT KETERANGAN**  
Nomor : 3707/UN3.1.1/PJ/2023

Yang bertanda tangan di bawah ini :

Nama : Dr. Sulistiawati, dr., M.Kes  
NIP : 196502281990032002  
Pangkat/Golongan : Lektor Kepala/ IVa  
Jabatan : Wakil Dekan III Fakultas Kedokteran Universitas Airlangga

Dengan ini menerangkan bahwa :

Nama : **Dr. Gondo Mastutik, drh., M.Kes.**  
NIP : 19730627 200212 2001  
Pangkat/Golongan : Pembina (IV/a)  
Jabatan : Lektor Kepala

Telah melaksanakan publikasi sebagai berikut :

Judul : Experimental and natural infections of severe acute respiratory syndrome-related coronavirus 2 in pets and wild and farm animals  
Penulis : Gondo Mastutik, Rohman A, I'tishom R, Ruiz-Arrondo I, de Blas I  
Jurnal : Veterinary World. 2022 Mar;15(3):565-589. doi: 10.14202/vetworld.2022.565-589. Epub 2022 Mar 10.


Artikel tersebut merupakan artikel review sehingga tidak memerlukan Keterangan Laik Etik (*Etical Clearance*).

Demikian surat keterangan ini kami buat untuk dapat dipergunakan sebagai persyaratan pengusulan Jabatan Fungsional **Guru Besar**.

Surabaya, 27 Maret 2023

a.n. Dekan  
Wakil Dekan III,



  
Dr. Sulistiawati, dr., M.Kes.  
NIP. 196502281990032002