A century of teaching veterinary parasitology in South Africa – Lessons learnt

Barend L. Penzhorn

Vectors and Vector-borne Diseases Research Programme, Department of Veterinary Tropical Diseases, Faculty of Veterinary Science, University of Pretoria, Private Bag X04, Onderstepoort, 0110, South Africa

Tel.: +27 12 529 8253; Fax: +27 12 529 8312; E-mail: banie.penzhorn@up.ac.za

ABSTRACT

Finding a healthy balance between classical parasitology and clinical veterinary medicine remains a challenge. Veterinary Parasitology, of vital interest in sub-Saharan Africa, has always featured prominently at the Faculty of Veterinary Science, University of Pretoria (founded in 1920). The faculty was initially an integral part of the Onderstepoort Veterinary Institute (OVI), and parasitology was taught by specialist researchers from OVI – a cult of total coverage prevailed. Presenting three separate courses – ectoparasitology, helminthology and protozoology – continued for many decades. From 1949 to 1973 an attendance course in veterinary parasitology was presented in the final academic year. This was revived in 1995, with a "refresher" in parasitology for final-year students (during their clinic rotation), including diagnostic parasite identification and problem-solving group discussions (prepared and led by

students). Student contact time (including practical classes and assessments), initially 80 hours/discipline/year, was gradually reduced. A species-based approach (introduced in 1998) had a major impact - an introductory course in general parasitology was followed by fragmented lectures in the subsequent 2 years on key parasitic diseases in the species-based subjects. In 2013 the curriculum reverted to being discipline-based, i.e. all aspects of parasitology and parasitic diseases covered during one academic year. The 3 sub-disciplines are included in a 2-semester course, with a total contact time of 100 h, which barely meets the minimum recommended by the WAAVP. Various lessons learnt are discussed.

Keywords: Curriculum development; South Africa; Teaching; Undergraduate; Veterinary Parasitology

1. Introduction

The Faculty of Veterinary Science of the University of Pretoria at Onderstepoort, South Africa, will be celebrating its centenary in 2020. This seems an opportune time to review the events shaping the structure of its veterinary parasitology curriculum, to assess the current situation and to spell out lessons learnt.

Finding a healthy balance between classical parasitology and clinical veterinary medicine at the undergraduate level remains a challenge. As teachers of veterinary parasitology, our core function is delivering functional veterinarians and not specialist parasitologists. This requires a skilful balancing act. On the one hand, practising veterinarians need not be overburdened with details that really belong in classical parasitology. On the other hand, as applied scientists,

veterinarians should grasp basic principles concerning parasitology; otherwise, the subject content will remain empiric knowledge probably acquired by rote learning. We have hopefully progressed beyond that approach!

Therefore, an ideal curriculum would be grounded in basic principles, e.g. understanding various basic lifecycles and having sufficient knowledge of parasite morphology to be able to recognise a specific parasite, or at least delegate it to a specific group. The second arm would concern the veterinary importance, e.g. host-parasite interactions and resultant clinical signs, control and prevention of disease. Parasites covered in the curriculum should, in my opinion, only be those that are relevant to the geographic area that the veterinary faculty is serving. That in itself would be a built-in safeguard against overloading the curriculum. The ideal academic staff complement at a university where veterinary science is taught should be a healthy mix of veterinarians and classical parasitologists, i.e. zoologists, as well as immunologists and molecular biologists. This should automatically lead to a healthy synthesis, with checks and balances from all sides.

Teaching of veterinary parasitology has benefitted greatly from advances in digital imaging, animation and development of virtual microscopy. These tools do not replace basic microscopy, however. For diagnostic purposes, microscopic examination of faecal smears and blood films, for instance, remains the appropriate technology and Day-1 competency, as recommended by the American Association of Veterinary Parasitologists (Snowden et al., 2016). Practising veterinarians still frequently use microscopes, not only for parasite identification but also for general cytology, etc.; hands-on use of microscopes should, therefore, remain a core competency of newly graduated veterinarians (Stewart et al., 2014).

Personal interests and personality traits of academic staff as well as student behaviour can impact on curriculation, teaching and assessment in veterinary parasitology (and probably other subjects). How these factors shaped the veterinary science curriculum at the University of Pretoria is described in the following sections.

2. South Africa: A look at the past

The Faculty of Veterinary Science, founded in 1920 at Onderstepoort, Pretoria, South Africa, was the first of its kind in Africa. For academic purposes, it was linked to the University of Pretoria, at that stage still the Transvaal University College, which awarded a Bachelor of Veterinary Science (BVSc) degree with a five-year curriculum (Anon., 1960). At its founding, the faculty was considered an integral part of the Onderstepoort Veterinary Institute (OVI). The first Dean, Sir Arnold Theiler, was also Head of OVI and his official title was Director of Veterinary Education and Research. The OVI resorted under the National Department of Agriculture; teaching was part and parcel of the duties of certain researchers at OVI. This situation continued until 1973, when the University of Pretoria assumed full responsibility for the faculty and full-time academic staff members were appointed (Spies and Heydenrych, 1987).

Veterinary parasitology is of vital interest in sub-Saharan Africa and has always featured prominently in the curriculum at Onderstepoort. Since parasitology was initially taught by specialist researchers from OVI, it is easy to see why a “cult of coverage” prevailed.

2.1 Evolution of departmental structure

After the ravages of the Rinderpest epidemic, which reached South Africa in 1896, and the on-going campaign to eradicate East Coast fever (theileriosis), introduced to southern Africa in 1902, infectious diseases were obviously high on the agenda of the fledgling faculty (Penzhorn and Krecek, 1994). In 1920 parasitology was included within the topic of Infectious Diseases, taught by Theiler himself (Gutsche, 1979). Although regarding himself primarily as a pathologist, he was an accomplished parasitologist. The University of Bern, Switzerland, awarded him a doctorate for his pioneering study on equine piroplasmosis (Theiler, 1901). The small tick-transmitted protozoan causing East Coast fever, initially regarded as immature *Babesia bigemina*, was named *Piroplasma parva* by Theiler (1904). The genus *Theileria* was established three years later and named in his honour (Bettencourt et al., 1907). Theiler (1910) identified, described and named the genus *Anaplasma* and, with a colleague, elucidated the life cycle of *Libyostrongylus douglassi*, a nematode of great economic importance in the ostrich industry (Theiler and Robertson, 1915). Theiler arranged for E.V. Cowdry from the Rockefeller Institute for Medical Research in New York, who was the leading authority on rickettsias, to visit Onderstepoort, where he confirmed Theiler's suspicion that heartwater, a major scourge of cattle, sheep and goats in sub-Saharan Africa, was caused by a rickettsia, now known as *Ehrlichia ruminantium* (Cowdry 1925a, 1925b).

The evolution of departmental structure concerning parasitology and infectious diseases is shown in Table 1. A separate Department of Helminthology was founded in 1923, under the leadership of the Italian-born Dr F. Veglia. He had been at Onderstepoort since 1911, where he did pioneering research on haemonchosis and nodular worms (Veglia 1915, 1923). At that stage,

ectoparasitology was also taught in the Department of Helminthology, but by a researcher from the Faculty of Agriculture, University of Pretoria. In 1927 Dr Veglia was succeeded by Dr. H.O. Mönnig, a South African zoologist who had received a doctoral degree in parasitology from the University of Zürich in 1921 and, on Theiler's recommendation, had qualified as a veterinarian in 1926 (Anon., 1978). His textbook *Veterinary Helminthology and Entomology* (Mönnig, 1934) gained world-wide recognition. The 4th edition was edited by Lapage (1956); protozoology was added in the 6th edition (Soulsby, 1968). A 7th edition was published in 1982, nearly 50 years after the first. Mönnig's meticulous line drawings will be familiar to many parasitologists of a previous generation.

Table 1. Evolution of the Department of Veterinary Tropical Diseases at the Faculty of Veterinary Science, University of Pretoria

Year	Name of department	
1920	Infectious Diseases[1]	
1923		Helminthology[2]
1928	Tropical Diseases and Protozoology	
1949	Protozoal and Viral Diseases	
1958	Infectious Diseases[1]	
1960		Parasitology
1974	Infectious Diseases	Parasitology and Protozoology
1976		Parasitology
1992	Veterinary Tropical Diseases	

[1]Including Protozoology

[2]Including Entomology (= Ectoparasitology)

In 1925 the Department of Infectious Diseases gave rise to the Department of Tropical Diseases, which from 1928 was called the Department of Tropical Diseases and Protozoology, headed by Dr P.J. du Toit. Twenty years later (1949) Bacteriology was split off, and the department renamed Protozoal Diseases and Virology, reflecting the main research interests of Dr W.O. Neitz, who was Head of the department (e.g., Neitz, 1939, 1948, 1956). This situation lasted for 10 years; the name of the department then reverted to Infectious Diseases. These divisions reflected the composition of research groups at OVI rather than fulfilling specific academic needs. Research on heartwater was conducted by the Section Protozoology and Virology of OVI, which focused on vector-borne diseases. For reasons that are obscure today, but probably relate to personal interests, heartwater was retained in the virology course when protozoal and viral diseases were split in 1974. It remains a moot point: the causative organism, *E. ruminantium*, is a bacterium. From a functional perspective, however, it is more meaningful to include this disease, as well as anaplasmosis, with vector-transmitted protozoa. In contrast to "classical" bacterial diseases, diagnosis of these two diseases is not based on bacterial culture but rather on direct demonstration of the causative organism in blood films or brain-crush smears.

In 1960 the Department of Helminthology (which included ectoparasitology) was renamed Department of Parasitology. In 1974 it became the Department of Parasitology and Protozoology, but the latter part of the name was dropped two years later. So, for the first time, the three classical divisions of parasitology were included in a single department (even though heartwater remained embedded within virology for another decade or so). In 1992 the Departments of Parasitology and Infectious Diseases merged to form the Department of Veterinary Tropical Diseases.

Table 2. Contact hours devoted to veterinary parasitology subjects at the Faculty of Veterinary Science, University of Pretoria (1923 to present)

	Year	Subject	Hours	Total
1923	3rd	Entomology	45	
		Helminthology	45	
	4th & 5th	Infectious Diseases (incl. Protozoology)	240	90+
1930	3rd	Entomology	45	
	3rd & 4th	Helminthology	90	
	4th & 5th	Infectious Diseases (incl. Protozoology)	240	135+
1940	3rd	Entomology	60	
	3rd & 4th	Helminthology	90	
	4th & 5th	Infectious Diseases (incl. Protozoology)	250	150+
1950	3rd	Entomology		
	4th	Helminthology		
	4th & 5th	Protozoal and Viral Diseases		
	5th	Practical Parasitology [1]		
1960	3rd	Entomology		
		General Protozoology and Virology		
	4th	Helminthology		
	4th & 5th	Protozoal and Viral Diseases		
	5th	Practical Parasitology[1]		
1963	3rd	Entomology		

		General Protozoology and Virology		
		Helminthology		
	4th & 5th	Protozoal and Viral Diseases		
	5th	Practical Parasitology[1]		
1974	3rd	Entomology		
		Helminthology		
		Protozoology		
	4th	Protozoal Diseases		240
1981	3rd	Entomology	60	
		Helminthology	80	
		Protozoology (incl. Protozoal diseases)	80	220
1986	3rd	Entomology	60	
		Helminthology	80	
		Protozoology	80	
	5th	Refresher in Parasitology[2]	6	226
1998	3rd	Veterinary Parasitology (excl. Protozoology)	60	
		Protozoology (in Immunology and Microbiology)	18	78
2006	4th	Introductory Veterinary Microbiology and Parasitology		
2014	3rd	Veterinary Parasitology		100

[1]Practical Parasitology: an attendance course (i.e., no examination) serving as refresher in Ectoparasitology and Helminthology; presented from 1949 to 1973.

[2]Refresher in Parasitology during clinic rotations during last two semesters of the BVSc course

3. Teaching the three parasitology disciplines

The various permutations in teaching the three parasitology disciplines, as well as the year of study during which they were presented, are shown in Table 2. The duration (in years) of the undergraduate programme at the faculty of Veterinary Science, University of Pretoria, is shown in Table 3.

Table 3. Duration of the academic programme and number of students admitted at the Faculty of Veterinary Science, University of Pretoria

Date	Students	Degree	Duration (years)
1920 – 1960	30	Bachelor of Veterinary Science	5
1961 – 1975	45	Bachelor of Veterinary Science	5
1976 – 1996	90	Bachelor of Veterinary Science[1]	5½
1997 – 2001	90	Bachelor of Veterinary Science[1]	6
2002 – 2005	120	Bachelor of Veterinary Science[1]	6
2006 – 2013	135	Bachelor of Science (Vet. Biology)[2] (3 yrs)	7
		Bachelor of Veterinary Science[1] (4 yrs)	
Since 2014	190	Bachelor of Veterinary Science[3]	6

[1]The last two semesters devoted to clinic rotations

[2]Awarded by the Faculty of Natural and Agricultural Sciences

[3]The last three semesters devoted to clinic rotations

3.1 A discipline-based curriculum

This was the norm from the inception of the Faculty (Table 2). Helminthology and ectoparasitology were regarded as separate entities, but protozoology was variously lumped with infectious diseases, in general, and later with virology, in particular. The contact time devoted to parasitology was gradually increased (Table 3). Unfortunately, the University of Pretoria yearbooks of the 1960s and 1970s do not specify the actual contact time devoted to subjects.

By the late 1970s, 240 h were devoted to veterinary parasitology, spread over the two 15-week semesters of the third academic year. The three disciplines Helminthology, Entomology (= Ectoparasitology) and Protozoology were taught by three full-time academic staff members; each subject was allocated 80 h of contact time, which included formal lectures as well as practical classes. During 1974-1980, an introductory Protozoology course was taught in the 3rd year alongside Entomology and Helminthology, followed by Protozoal Diseases during the 4th year. From 1981, Protozoal Diseases was included in the 3rd year protozoology course. In view of overloading of the curriculum, leaving virtually no free time for the students, the Dean at the time requested academic staff to scrutinise all courses and cut down on content and student contact time, without jeopardising standards. The entomology lecturer volunteered to sacrifice 20 hours of contact time, which, unfortunately, was promptly allocated to another subject (I.G. Horak, personal communication).

A limitation of this discipline-based approach was that the courses were presented relatively early in the veterinary programme. Introductory pathology and pharmacology were presented in the same academic year. The upshot was that, in order for students to have a better

understanding of the clinical situation, lecturers in the parasitology subjects had to spend a lot of time explaining basic concepts in other disciplines, such as pathology and pharmacology.

A discipline-based approach was also followed by the Faculty of Veterinary Medicine, Medical University of Southern Africa (Medunsa), which admitted its first students in 1982. During the 4th year of a 6-year academic programme, 224 h contact time was devoted to Helminthology, Protozoology and Veterinary Entomology (Verster, 1994). The Faculties of Veterinary Science of Medunsa and University of Pretoria merged in 1999 (Verwoerd and Bigalke, 2008).

3.1.1 Practical classes

Practical classes comprised between 13% and 40% of the contact time in the three disciplines (Verster, 1994). The lecture halls in the new faculty buildings, inaugurated in 1987, had raked floors and were spacious enough for a locker to be placed next to every seat. The 90 students (Table 3) were each issued a stereo-microscope and a compound microscope fitted with an oil-immersion lens as well as a McMaster slide, various pipettes, a counting chamber, etc. (Verster, 1994). Each student received more than 150 specimens, to be used during practical classes and for revision. These comprised mounted specimens of helminths, protozoa, mites, small insects, insect mouthparts and wings, as well as alcohol-preserved specimens of ticks and flies.

The period 1987–2001 can be regarded as the hey-day of teaching veterinary parasitology. Audio-visual aids in the lecture hall included colour slide (later PowerPoint) projection, an overhead projector and monitor screens linked to a microscope. To assist students while studying

specimens under their microscopes, photographs, line drawings and images of actual specimens could be projected. Three academic staff members and three technologists were on hand to assist, a ratio of one mentor to 15 students. Practical classes were not solely focused on specimen identification, but in helminthology also on specimen recovery and quantification by collecting from intestines or by faecal flotation.

Assembling and maintaining an extensive specimen collection was extremely labour-intensive and costly. When the annual intake of undergraduates was doubled from 45 to 90 in 1976 (Table 3), a sufficient number of sets of specimens was still available. By 2002, when the intake was increased to 120 undergraduates (Table 3), however, resources were strained and pairs of students had to share a set of specimens.

The format of practicals remained unchanged until 2013, when student intake increased to 190 and the lecture halls, planned for 120 students, were remodelled to increase the number of seats. The individual lockers were removed, and microscopes moved to a newly built multidisciplinary teaching laboratory. Sets of specimens are no longer issued to students.

3.1.2 Formal parasitology instruction in the final year of study

Formal refresher courses in parasitology (helminthology and ectoparasitology) were included in the final academic year between 1949 and 1973 (Table 2). Although there was no examination, attendance was compulsory. In 1986 a 6-hour “refresher” in parasitology was introduced during the clinical rotation of final-year students, which included diagnostic parasite identification, as well as problem-solving case-study group discussions prepared and led by

students (Table 2). This has fallen by the wayside, reinforcing the chasm between pre-clinical and clinical subjects.

3.2 A host species-based curriculum (1998)

During the 1990s the curriculum at the Faculties of Veterinary Science of the University of Pretoria was thoroughly reassessed, and a species-based approach was adopted for the clinical subjects. The implication for parasitology was that an integrated introductory course would be presented in the preclinical phase, while clinical aspects would be presented later by the parasitology lecturers in host species-based courses. Subsequently, "Introductory Veterinary Parasitology" was created, but it included only helminthology and ectoparasitology. Against the wishes of the parasitologists, Protozoology was included with "Immunology and Microbiology", since a curriculum committee member from another discipline argued that protozoa, as microscopic organisms, were included in some general microbiology textbooks and thus should be separated from the other parasitology subjects.

The host species-based approach had a major impact on teaching veterinary parasitology - after the introductory course, lectures on parasitic diseases were presented in a highly fragmented time-table. Some of these courses, e.g. small animal and bovine, were further divided into organ systems. The advantage of this approach was that the parasitology academic staff members were directly involved in teaching clinical subjects.

3.2.1 Examination matters

Due to a tendency by some course coordinators of host species-based courses to allocate marks for test and examination questions pro-rata the number of lectures given, parasitology topics became "swamped" by other clinical topics. For example, in Equine Health one 40-min lecture was devoted to dourine (a gazetted controlled disease in South Africa) and equine piroplasmosis (probably the most important cause of abortion in horses in South Africa), respectively. When the final examination paper was set, the lecturer involved was routinely requested to submit two multiple-choice questions, counting one mark each, to cover these diseases – a patently ludicrous situation. The students soon learnt that it was more profitable to focus their preparation on the subject matter taught by clinicians, to the detriment of parasitology and other paraclinical subjects. The upshot was a perceived general decrease in the knowledge of parasitic diseases in newly qualified veterinarians. This was one of the subjective reasons for reverting to a discipline-based curriculum (see section 3.3).

3.2.2. Extending the duration of the undergraduate course

During this period, radical restructuring of the course took place (Table 3). The 6-year BVSc course was replaced by a 3-year Bachelor of Science (Veterinary Biology) as prerequisite for a 4-year Bachelor of Veterinary Science, i.e. the course was extended to 7 years. This did not impact on teaching veterinary parasitology, except that the introductory course was presented during the 4th year of study and not in the 3rd year.

3.3 Reverting to a discipline-based curriculum

In 2013 the undergraduate programme reverted from 7 to 6 years; course work is completed in 4½ years and the last three semesters are devoted to clinical rotations (private practice, etc.). At the same time, student intake was increased to 190. The curriculum reverted to the original approach, i.e. all aspects of parasitology covered during one academic year. The 3 sub-disciplines are included in a 2-semester course in the 3rd academic year, with total contact time of 100 h, which includes practical classes and on-going assessments. This curriculum complies with the WAAVP's recommendations of a minimum of 70-90 h devoted to basic parasitology using a discipline-based approach (Krecek, 2002). Whether it complies with the WAAVP's recommendation of 10-20 hours of advanced teaching of parasitology is debatable. In a retrograde step, the final-year "refresher" in parasitology was abolished, serving to underline the division between preclinical and clinical subjects in the minds of students and lecturers alike.

Students receive a study-guide to the 2-semester course in veterinary parasitology, which clearly stipulates the learning objectives for each of the three sub-disciplines. Comprehensive study notes can be downloaded from the University of Pretoria website. PowerPoint presentations used during lectures can also be downloaded by students.

3.3.1 Practical classes

Due to a shortage of resources, students are no longer issued with sets of specimens. Presentation of practical aspects differs among the three sub-disciplines. In Helminthology there is one 2-h practical class during which students learn to perform faecal flotations, etc. Helminth

identification is by means of demonstration. The nematode, cestode and trematode specimens are on display for one week, respectively. Staff members are on duty to answer questions, and students have to study the specimens and sign an attendance register. In protozoology there are two 2-h practical sessions where microscopes with specimens are set up. In ectoparasitology four 2-h sessions are devoted to practical instruction. Groups of students share sets of specimens. A total of 14 h of contact time (14%) is devoted to practicals. It is too early to assess the level of competency in parasitology of graduates who followed the new curriculum.

4. Lessons learnt

- Despite advances in molecular biology, for example, basic microscopy remains appropriate technology for diagnosing many parasite-related diseases.
- A "cult of coverage" should be avoided; curricula should focus on locally relevant parasites.
- By using appropriate aids, newly qualified veterinarians should be able to identify economically important parasites.
- Structuring curricula or departments to suit the research interests of academic staff is not in the best interest of students.
- When a curriculum is revised, decisions should be based on objective assessment and not made subjectively.
- In a host species-based curriculum, relevant parasitology-based questions should be included in final-year student assessment.
- The requirements for practical training should be clearly spelled out in the curriculum, and not left to the discretion of the academic staff involved.

- To erase the gap between perceptions of pre-clinical and clinical (in the minds of both academics and students), lecturers in parasitology subjects should actively interact with senior undergraduates during the clinical rotations.

Acknowledgements

This review is dedicated to Ivan Horak and to the memory of Anna Verster and Richard Reinecke, who mentored me in parasitology. I thank Prof Luis Neves, Dr Hein Stoltsz and Dr Volker Schwan for providing information, and Ms Susan Marsh and other staff of the Jotello F. Soga Library for assistance in tracing references.

References

Anon., 1960. Ad destinatum 1910-1960: Gedenkboek van die Universiteit van Pretoria. Voortrekkerpers, Johannesburg, 470 pp.

Anon., 1978. In memoriam Prof. Dr. H.O. Mönnig. J. S. Afr. Vet. Assoc. 49, 384.

Bettencourt, A., França, C., Borges, I., 1907. Addendum â nota sôbre piroplamose dô gamo. Revta. Med. Vet., Lisb. 6, 37-40.

Cowdry, E.V., 1925a. Studies on the aetiology of heartwater. I. Observation of a rickettsia, *Rickettsia ruminantium* (n. sp.) in the tissues of infected animals. J. Exp. Med. 42, 231-252.

Cowdry, E.V., 1925b. Studies on the aetiology of heartwater. II. *Rickettsia ruminantium* (n. sp.) in the tissues of ticks transmitting the disease. J. Exp. Med. 42, 253-274.

Gutsche, T., 1979. There was a man: the life and times of Sir Arnold Theiler, K.C.M.G., of Onderstepoort. Howard Timmins, Cape Town, 487 pp.

Krecek, R.C., 2002. Resolution on teaching veterinary parasitology, World Association for the Advancement on Veterinary Parasitology (WAAVP). Vet. Parasit. 108, 333-335.

Lapage, G., 1956. Mönnig's veterinary helminthology and entomology (4th edition). Baillière, Tindall and Cox, London, 511 pp.

Mönnig, H.O., 1934. Veterinary helminthology and entomology; the diseases of domesticated animals caused by helminth and arthropod parasites. Baillière, Tindall and Cox, London, 402 pp.

Neitz, W.O., 1939. The immunity in heartwater. Onderstepoort J. Vet. Sci. Anim. Ind. 13, 245-283.

Neitz, W.O., 1948. Immunological studies on bluetongue in sheep. Onderstepoort J. Vet. Sci. Anim. Ind. 23, 93-136.

Neitz, W.O., 1956. Classification, transmission, and biology of piroplasms of domestic animals. Ann. N. Y. Acad. Sci. 64, 56-111.

Penzhorn, B.L., Krecek, R.C., 1997. Veterinary parasitology in South Africa: Some highlights of the past 100 years. Vet. Parasit. 71, 69-76.

Snowden, K.F., Krecek, R.C., Bowman, D.D., 2016. AAVP recommendations for core competency standards relating to parasitological knowledge and skills. J. Vet. Med. Ed. 43, 344-348.

Soulsby, E.J.L., 1968. Helminths, arthropods and protozoa of domesticated animals (6th edition of Mönnig's Veterinary Helminthology and Entomology). Baillière, Tindall and Cassel, London, 824 pp.

Spies, F.J.duT., Heydenrych, D.H., 1987. Ad destinatum II 1960-1982: 'n Geskiedenis van die Universiteit van Pretoria. University of Pretoria, Pretoria, 435 pp.

Stewart, S.M., Dowers, K.L., Cerda, J.C., Schoenfeld-Tacher, R.M., Kogan, L.R., 2014. Microscope use in clinical veterinary practice and potential implications for veterinary school curricula. J. Vet. Med. Ed. 41, 331-336.

Theiler, A., 1901. Die Pferde-malaria. Schweizer Arch. Tierheilk. 43, 253-280.

Theiler, A., 1904. Rhodesian tick fever. Transv. Agric. J. 2, 421-438.

Theiler, A., 1910. *Anaplasma marginale* (gen. and spec. nov.); the marginal points in the blood of cattle suffering from a specific disease. Rep. Gov. Vet. Bacteriol. Transv. 1908-1909, 7-64.

Theiler, A., Robertson, W., 1915. Investigations on the life history of wire worm in ostriches. Rep. Vet. Res. Un. S. Afr. 3 & 4, 291-345.

Veglia, F., 1915. The anatomy and life history of the *Haemonchus contortus* (Rud.). Rep. Vet. Res. Un. S. Afr. 3 & 4, 349-500.

Veglia, F., 1923. Preliminary notes on the life history of *Oesophagostomum columbianum*. Rep. Vet. Res. Un. S. Afr. 9 & 10, 809-829.

Verster, A., 1994. Teaching veterinary parasitology. Vet. Parasit. 54, 269-281.

Verwoerd, D.W., Bigalke, R.D., 2008. Onderstepoort 1908-2008. Veterinary History Committee of the South African Veterinary Association, Pretoria, 216 pp.