Veterinary Informatics: State-of-the-Art and the Role of Librarians
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Abstract
This narrative review provides an overview of recent advances in veterinary informatics, confirms the ongoing role of librarians in informatics, and discusses future drivers of informatics initiatives. The author identifies articles published over the last decade relevant to veterinary informatics, topics discussed at recent veterinary and biomedical informatics conferences, and emerging informatics resources.

Areas covered include the adoption of mobile technology and telemedicine, the impact of artificial intelligence on veterinary literature searching, electronic health record (EHR) interoperability initiatives, big data studies and capabilities, and the emergence of geographic and pharmacogenomics precision medicine. Librarians maintain a critical role in identifying novel and needed research questions and methodologies, applying metadata and standards, and searching collections both inside and outside the library. The review concludes with a reflection on possible drivers of ongoing funding, and motivations for veterinary informatics initiatives and projects.
Introduction

As information formats evolve, librarianship and informatics both stake claims on information. Both disciplines seek to support decision-making, and to create a learning system that improves patient and population health. Informatics is becoming an essential realm of knowledge and a new outlet for librarian expertise, while moving beyond librarianship to create systems that shrink the gap between veterinary research and practice.

Publications on informatics are organized in a variety of ways, reflecting the many stakeholders seen as audience. Recent health informatics textbooks and reviews are structured to look at theories and definitions, information systems and applications, data standards, clinical decision-making, participatory health, information life cycle, workflows and user experience, change management, security and policy, education and international collaboration. (Nelson and Staggers, 2018, Gardner et al., 2009) Several publications have reviewed the state of veterinary informatics over the years. In 1991, Talbot looked at available literature databases, information systems, methods for future artificial intelligence enabled clinical decision support, education, and the potential for research to handle large volumes of data. (Talbot, 1991) At the time, artificial intelligence (AI) was largely theoretical and limited to supervised probability based linear regression, Bayesian classification, decision trees, and expert systems that rely on if-then rules. It is interesting that while artificial intelligence was added as a National Library of Medicine (NLM) Medical Subject Heading (MeSH) term in 1986, machine learning was not added until 2016. This was after Smith-Akin’s 2007 analysis of the MEDLINE indexed literature on veterinary informatics that identified descriptors and gaps in research. Alpi’s International Conference of Animal Health Information Specialists (ICAHIS) survey study conducted in 2009 identified organizations involved in informatics, informatics-enabled studies by US educational institutions, present and future uses of informatics, and areas for librarian involvement. (Alpi, 2009) Alpi talked about the difficulty in distinguishing between informatics and information technology. A low survey response rate at the time likely reflects a generalized lack of knowledge surrounding the topic of informatics. A special issue of the Journal of Veterinary Medical Education (JVME) in 2011 on veterinary information included a review of veterinary standards and controlled vocabulary, (Santamaria and Zimmerman, 2011) and an overview of the
functional areas of informatics as they pertain to one academic institution. (Johnson et al., 2011) These functional areas included data management, education, herd management and electronic health record (EHR) systems, biomedical research and interdisciplinary collaboration. Most recently, Allen reviewed veterinary electronic health record systems in comparison to those for humans. (Allen, 2017, Jan. 23)

This review will revisit these previous themes and look at informatics areas that have changed or grown over the last decade including precision medicine, One Health as a driver of health information exchange, and growing big data and AI capabilities. It will not discuss bioinformatics except as it has application to clinical informatics. Informatics is poised to play a larger role in medical curriculum development as AI enabled systems emerge in health care settings. One hesitates to tackle the topic of informatics as it defies scope, changes rapidly, (Chen and Sarkar, 2015) and is likely to reveal glaring gaps in knowledge. That is exactly why frequent updates are needed.

**Organizations and Collaborative Efforts**

Informatics relies on collaborative effort for interoperability and standards to move forward. Several examples of this emerged in the UK in the last decade with the support of both large veterinary organizations like the Royal College of Veterinary Surgeons (RCVS), and academic institutions. (Mellanby, 2017) The Veterinary Companion Animal Surveillance System (VetCompass) began as a pilot project under the Royal Veterinary College in 2007 with a small animal emphasis. (Jones-Diette et al., 2016, O'Neill, 2013, O'Neill et al., 2017a, O'Neill et al., 2017b, O'Neill et al., 2016) It has now become an international effort, (Muellner et al., 2016, McGreevy et al., 2017) with multiple academic, private practice, and professional organization partners and an equine branch. At the same time, the Small Animal Veterinary Surveillance Network (SAVSNET) began in 2008 as a collaboration of the British Small Animal Veterinary Association (BSAVA) and the University of Liverpool, combining laboratory and private practice data. (Mellanby, 2015, Mellanby, 2017)

In the United States (US) dissociated veterinary informatics initiatives and technology efforts have struggled. (Johnson et al., 2011) The American Veterinary Medical Association (AVMA) has not led the profession in technology adoption beyond the recent Animal Health Studies Database. (American Veterinary Medical Association) While no large-scale studies of veterinary
electronic health record (EHR) adoption have been completed in the US, one study completed in 2010 in Massachusetts showed an approximate self-reported 20% of veterinary practices using print records only, 17% using EHRs only, and 63% using a combination of print and electronic records. (Krone et al., 2014) However, only 50% of small (two or fewer doctor) practices used any form of EHRs, and only 60% of practices using EHRs at least partially were recording medical and surgical information, with only 40% or fewer of those practices extracting patient health information for analysis. This study did not assess the capacity for health information exchange between these systems. Since this study survey was completed, human medicine benefitted from the Health Information Technology for Economic and Clinical Health (HITECH) Act passed in 2009, which provided incentives to medical and allied health providers for adoption and meaningful use of electronic health records. More than half of eligible US human health care providers received Meaningful Use payouts between May 2011 and February 2018. (Centers for Medicare and Medicaid, 2018) These incentives for technology use in human medicine have left many veterinary practices behind technologically, contributing to a widening informatics gap. At the same time, problems with the rapid adoption of health information technology in human medicine (Coiera et al., 2016) have left veterinarians less willing to fully adopt electronic systems.

In North America, much of the large-scale interest and impetus for informatics initiatives over the last decade has come from private industry, vendors, and large hospital groups. The Association for Veterinary Informatics (AVI) strives to bring dispersed international stakeholders together in conversation at their annual Talbot Symposium. They define veterinary clinical informatics as “a rapidly evolving science that blends information technology, communications, social and behavioral science, and veterinary medicine, to improve the quality and safety of patient care.” Other professional organizations are also invested in informatics, such as the American Animal Hospital Association (AAHA) which has worked on a diagnostic code list and a cross-vendor microchip finder database, (American Animal Hospital Association) and the American College of Emergency and Critical Care’s (ACVECC) VetCOT initiative for veterinary trauma certification and research. (Hall and VetCOT Trauma Registry Subcommittee, 2015) Much of the information on informatics initiatives disseminates in private conversations, conferences without indexed proceedings, vendor contracts, and proprietary corporate practices. Smaller practices, which still make up a majority of the profession and hold decision making
power in large US veterinary professional organizations, may perceive informatics as contributing to growing corporate practices that have invested heavily in data collection initiatives to improve practice for decades. (Banfield Pet Hospital, Kass et al., 2016) Therefore, the real drivers for meaningful informatics adoption may be growing interest in One Health (Martins et al., 2016, Johnson et al., 2018, VanderWaal et al., 2017) and, to a lesser extent, animal welfare and the human-animal bond. These initiatives require collaboration with interested groups outside the profession.

Many US land grant universities were impacted by dwindling state education funding over the last decade, limiting the ability of some veterinary schools to update their information systems and provide manpower and expertise for outreach to veterinary populations. As well, veterinary schools are a small market niche with a daunting need to combine complex and interdisciplinary academic, research, health and herd data. This tall order may be potentially unattractive to standard information system developers. There are two veterinary institution-based collaborations for large-scale data collection in the US, the Veterinary Medical Database (VMDB) currently housed at the University of Missouri with 9 US schools, and the Clinical and Translational Science Award One Health Alliance (COHA/CTSA) with 15 US schools involved and NIH funding. (Clinical and Translational Science Award (CTSA)) The COHA group intends to use REDCap for data management. (The National Center for Advancing Translational Science, 2017)

Other informatics initiatives that have garnered government support reflect a growing interest in One Health at the US national level. A few examples are the electronic Certificate of Veterinary Inspection (eCVI) travel health certificate program data standards developed through the United States Animal Health Association (USAHA), (United States Animal Health Association) the National Animal Health Laboratory Network (NAHLN), the United States Geological Survey’s (USGS) Wildlife Health Information Sharing Partnership (United States Geological Survey) and the Food and Drug Administration (FDA) system for veterinary adverse events reporting. (United States Food and Drug Administration) Disparity of reporting systems between US agencies has likely added to confusion among veterinarians and others for decades. For instance, veterinary vaccine and biological adverse events report to the United States Department of Agriculture (USDA), while animal drug, device and food adverse events report to the FDA. In
addition, government agencies often report data months to years after collected in the form of published pdf reports, rather than in real-time systems that might more effectively impact veterinary decision-making.

Large-scale prospective veterinary cohort studies are becoming a reality in veterinary medicine, in a large part due to animal caregivers self-enrolling their own pets and/or transparent visualization of laboratory data. These include the Golden Retriever Lifetime Study funded by the Morris Animal Foundation and corporate partners, (Morris Animal Foundation) the Pet Insight Project using pet fitness trackers from Banfield, (Whistle Labs Inc.) the National Veterinary Cancer Registry collaboration of Baylor and Texas Oncology Group, the DogsLife study of healthy dogs through the University of Edinburgh, (University of Edinburgh, Clements et al., 2013, Pugh et al., 2016, Pugh et al., 2017) the Bristol Cat Study of healthy cats, (University of Bristol) and the Dog Aging Project at the University of Washington. (University of Washington, Jin et al., 2016, Kaeberlein et al., 2016, Mazzatenta et al., 2017) The Orthopedic Foundation of America (OFA) makes retrospective breed data available for genetic disorders. (Orthopedic Foundation for Animals(OFA)) Real time data visualizations are available from laboratories collaborating with the Cornell Veterinary Laboratory on canine influenza incidence, (Cornell University) and from the Companion Animal Parasite Council (CAPC) on veterinary parasite prevalence in North America. (Companion Animal Parasite Council(CAPC)) The availability of these large databases comes with growing discussion and study of the validity of secondary databases with regards to manual and computerized data transfer. (Rintakoski et al., 2012)

Much of informatics is designed to address local needs and represent local needs within a global context. Veterinary medicine worldwide has traditionally relied on mandatory reporting at an international, national, and autonomous region level. Thus, many informatics tools are directed at enabling and prioritizing reporting within a regional or cultural context. (Hattendorf et al., 2017) For example, DISCONTOOLS identifies research gaps and prioritizes vaccine development for infectious animal diseases in Europe. (O'Brien et al., 2017) A Glasgow based company Cojenga started VetAfrika in 2014 that provides app based reporting of animal disease for African farmers with limited access to veterinary care. (Beyene et al., 2018) A similar effort in Switzerland relies on veterinary electronic reporting of disease that falls outside official
notifable lists with the Equinella reporting system for equine infectious disease. (Muellner et al., 2015) The burden of veterinary disease reporting is currently most likely left to animal health laboratories and designated government animal health agents. Recent studies looking at the validity of self-reporting systems from both producers and veterinarians show under-reporting, resulting in a growing interest in new automated computerized systems that incorporate reporting into workflows. (Mörk et al., 2010)

There are a number of international information systems in use or in development for animal health and disease surveillance. (Wendt et al., 2015) One of the model systems for veterinary medicine is the Zoological Information Management Software (ZIMS) or Species360. (Species360) This database was developed with the support of corporate sponsors and funding agencies. Over 1100 zoos, aquariums and wildlife groups contribute husbandry, genetic, health and conservation data available to users in real-time. The International Society for Infectious Diseases maintains the Program for Monitoring Emerging Diseases (ProMED). (International Society for Infectious Diseases) It not only provides rapid disease updates, but also follows up with descriptions of the decision-making process followed in response. This aspect is most critical and underutilized by veterinarians. As well, the World Organisation for Animal Health (OIE) provides the World Animal Health Information Database (WAHID). (World Organisation for Animal Health (OIE)) To support this effort, the Food and Agriculture Organization of the United Nations (FAO) has developed a new Laboratory Mapping Tool to standardize assessment of laboratory safety and biosecurity. (Mouillé et al., 2018) All continue to improve user interfaces and alert systems. The next step is interoperable data and standard data identifiers that allow veterinary data to combine in interdisciplinary studies and decision support systems. One example is the Swine Health Information Center (SHIC) established by the pork industry and swine veterinarians in the US that utilizes ProMED data.

**Standards**

Standards for vendor neutral global data are developing, though each veterinary specialty, research discipline, and geographic area has their own standards group.

Two veterinary clinical terminology standards underlie veterinary systems. The first is the veterinary extension of SNOMED CT developed by the Veterinary Services Terminology Laboratory (VTSL) at Virginia Tech. (Veterinary Terminology Services Laboratory) SNOMED
began as a terminology developed by the College of American Pathologists. VTSL developed terminology for AAHA, AAEP, USDA, and the NAHLN. The second is the VeNOM terminology used by VetCompass in the UK. (VeNOM Coding Group) VetCompass now relies more heavily on natural language processing.

The Veterinary International Conference on Harmonization (VICH) is standardizing the International Technical Requirements for Registration of Veterinary Medicinal Products. (HealthforAnimals) They publish study design recommendations.

Large collaborative international groups are working on electronic health record data standards through Health Level 7 (HL7) (Awaysheh et al., 2018) or Observational Health Data Sciences and Informatics (OHDSI) Observational Medical Outcomes Partnership (OMOP) Common Data Model (CDM) based at Columbia University. (Observational Health Data Sciences and Informatics (OHDSI)) While the UK has had an active group called VetXML working on veterinary EHR interoperability since 2006, (Society for Practising Veterinary Surgeons (SPVS)) there has been less collective effort for interoperability of veterinary EHR systems in the US.

The universal standard for radiology picture archiving and communication systems (PACS), labeled digital imaging and communication in medicine (DICOM) has remained largely unchanged in the last decade, though image resolution and adoption of digital radiography by private practices continues to improve.

Standards exist in human medicine for exchange of clinical research data called the Clinical Data Interchange Standards Consortium (CDISC) Biomedical Research Integrated Domain Group (BRIDG), (Clinical Data Interchange Standards Consortium (CDISC)) and for integration of bench and clinical data through the NIH funded I2B2 project. (i2b2 tranSMART Foundation)

Also of importance to veterinarians is the G8 Summit commitment to the New Alliance for Food Security and Nutrition Agriculture’s Global Open Data for Agriculture and Nutrition (GODAN), (New Alliance for Food Security and Nutrition Agriculture) and the International Committee for Animal Recording (ICAR) that works on standards and guidelines for animal identification and evaluation.

However, few of these international efforts have trickled down to the level of individual clinicians or researchers. It may be helpful in understanding the complexity of this issue to know
that in the US no American Medical Association (AMA) interoperability group existed until 2017 with formation of the Integrated Health Model Initiative (IHMI). (American Medical Association)

**Information systems**

The emphasis and focus here is on electronic health record systems recording clinical medical and surgical information beyond practice management functions. However, it is important to consider that herd management systems and breeding management systems, (Chastant-Maillard et al., 2017) as well as management software for kennels, pet groomers, barns, animal shelters, wildlife and laboratory animals has reason to be interoperable with veterinary records to contribute to the greatest well-being of the whole animal and the public. While sophisticated herd management systems have been utilized for decades, they lack the HL7 standard needed for interoperability with other health information systems. There are numerous vendors of veterinary software systems and few resources for effectively comparing them. As well, corporate veterinary practices use their own proprietary software (Banfield Pet Hospital, Veterinary Centers of America (VCA Inc.)) and veterinary teaching hospitals use vendor or homegrown software that fits their unique needs for teaching and research. As a result of struggling initiatives for interoperability of electronic health records systems, third party applications such as VitusVet are placing health information exchange, particularly important during disasters and emergencies, in the hands of animal caregivers.

**Supporting Technology and Interoperable Systems**

External to these information systems are a number of supporting technologies. There is no standard application programming interface (API) for incorporating these supporting technologies, and no conventions for data ownership or interoperability. (Alawneh et al., 2018b)

Imaging includes the modalities of x-ray, magnetic resonance imaging (MRI), computed tomography (CT), ultrasound, fluoroscopy, scintigraphy and thermography. Most veterinary practices have replaced traditional film radiography with digital systems, due to both time saved and growing environmental regulations associated with print films. These digital systems may still lie unconnected to a patient’s EHR though due to the large storage capacity required for PACS, thus limiting their capacity for teleradiology. Radiology may be targeted for automation
as teleradiology and artificial intelligence enabled pattern recognition create the ability to outsource radiographic interpretation. (Jha and Topol, 2016) In a similar way, sound can be differentiated with pattern recognition. AI and Bluetooth enabled stethoscopes are now available commercially and audio pattern recognition is able to detect BVD in auscultated feedlot cattle. (Mang et al., 2015, Timsit et al., 2016)

Radiology is not the only area of growing telehealth ability, as more systems now exist for remote sensor monitoring and assessment. As well, Google glass enabled remote examination scribes promise to give doctors more time with their patients. Veterinarians are struggling to define the limits and potential of telehealth in patient-centered veterinary care. Much of telemedicine is dependent on the growing internet of things, often in the form of wearable devices that can inform or control patient care including limb sensors for gait analysis, fitness trackers, encapsulated cameras for endoscopy, automated feeders, and monitors for body temperature, blood glucose, estrus, EKG, urine output, and appetite. (Neethirajan et al., 2017, Rodriguez and Record, 2017) All can contribute to patient health data and condition monitoring. (Neethirajan et al., 2017, Swain et al., 2017)

Related participatory systems in human medicine allow for e-patient engagement ranging from client portals to direct input of client contributed or wearable device data to the EHR. This is not new to dairy veterinarians who have worked closely with herd management data for decades, with measurable outcomes in terms of increases in production. Starting in 2018 US physicians that participate in the Centers for Medicare and Medicaid Merit-Based Incentive Payment System can charge for analyzing wearable device data. (Frelick, 2018, April 22)

Mining of anonymized electronic health record data can contribute to both quality improvement and surveillance for emerging infectious disease on both a local and national level. Retrospective analysis of patient records has been standard in veterinary teaching hospitals, but now the technology exists to do it in real time, in non-referral settings, and in a way that can inform current local practice. An example of this is the ability to identify trends in local antibiotic resistance in a small animal practice setting. (Lustgarten, 2017) Practice data can provide even more powerful surveillance capacity when combined with population big data from social media and web searches, (Wendt et al., 2015, Wendt et al., 2016, Kass et al., 2016, Arsevska et al.,
Mobile medical apps that may or may not be connected with wearables are popular with people; even if there is little evidence of their overall effectiveness. (Noah et al., 2018) What they can do is engage the patient in their own health. However, in herd management, where production and health data has been carefully tracked for decades, these apps and wearables are becoming instrumental in early detection of conditions like ketosis. (Bayer) For small animal veterinary clients mHealth apps provide appointment and medication reminders, fitness tracking, first aid instruction, behavior assessment and training, pet sitting providers, travel advice, disease summaries and GPS tracking. These veterinary apps have become sophisticated tools for building trust and engagement, and many apps easily integrate with insurance.

Sensor data that detects disease, environmental conditions, or physiologic parameters is not the only means of providing data driving precision medicine. (Neethirajan et al., 2017, Swain et al., 2017) Genomic data is already routinely used in veterinary medicine with MDR1 testing for ivermectin sensitivity, and is a growing area of study. (Wilkin et al., 2017, Raffan et al., 2016, Anturaniemi et al., 2017, Yeo, 2017, Mankowska et al., 2017) What has yet to materialize in both human and veterinary medicine is standard systems that incorporate precision medicine into electronic health record treatment plans, or that alert providers to the need to consider precision medicine. The Monarch Initiative is a database linking cross-species phenotypes and genotypes in a way that may eventually aid in this effort.

Decision support is a somewhat contentious term as vendors clamor to use the term for any point-of-care resources. Instead, a better phrase might be “context sensitive decision support,” used to describe HL7 enabled decision support linked to the patient record and data. (Contalbrigo et al., 2017) Melton has shown that computerized provider order entry (CPOE) alerts improve patient safety only when well designed, and context specific to prevent alert fatigue. (Melton, 2017) Pharmaceutical alerts constitute one of the biggest potential areas for improving patient outcomes, while also being an area for potential alert fatigue. (Coiera et al., 2016) Decision support systems combining multiple data sets exist currently for dairy herds, (Alawneh et al., 2018a) and AI neural networks have been shown to make accurate predictions from small animal
clinical data, (Torrecilha et al., 2017) though the extent to which these systems are interoperable and HL7 enabled in addition to being context specific is not determined.

Veterinary laboratories play a key role in animal health through disease surveillance. Veterinary diagnostic testing relies on a combination of in-house laboratory testing, private laboratories, institutional laboratories, national animal health laboratories, and human public health laboratories. In the US state laboratories are joined through the National Animal Health Laboratory Network (APHIS) While large private laboratories have been quick to integrate seamless computerized physician order entry (CPOE), some institutional and NAHLN laboratories still rely on print systems that do not match current private practice workflows. Christopher argues that clinical veterinary laboratory informatics is a needed sub-specialty. (Christopher and Hotz, 2000)

Medical records can also incorporate permanent International Organization for Standardization (ISO) standard Radio-Frequency identification (RFID) animal identifiers now available with vendor-neutral universal readers. The World Small Animal Veterinary Association (WSAVA) Microchip Subcommittee has worked to adopt global ISO standards and implantation sites for all species. (World Small Animal Veterinary Association (WSAVA)) The International Committee for Animal Recording (ICAR) coordinates guidelines and standards specifically for animal identification. ISO standards are implemented in Canada, Europe, Asia, and Australia. At this time pet microchips in the US and Africa cannot be considered an ISO standard permanent identifier. AAHA has established a universal pet microchip lookup database that points to companies associated with a given number. (American Animal Hospital Association)

University teaching hospitals, and a growing number of partnering private hospitals, have additional needs for systems that serve teaching and research. These needs include student access (Welcher et al., 2018) and standard informed consent to support big data use and long-term cohort studies. (British Small Animal Veterinary Association) In addition, an increasing number of educational programs need to track student outcomes in distributed models of clinical education. (Johnson et al., 2011)

Several authors have explored the incorporation of point-of-care information resources into electronic health records using the HL7 Context-Aware Knowledge Retrieval Application Infobutton standard. (Alpi et al., 2011, Teixeira et al., 2017, Higgins et al., 2017, Cook et al.,
Infobutton searches include characteristics of the patient, provider, clinical setting and clinical task in the query. Despite health care providers voicing an interest in access to multiple information resources through Infobutton capability, studies in clinical settings show that the infobutton is used less than 8 times per month, and users rarely consult more than one resource. This low usage was attributed to indexing, leading to one recent study that showed machine learning is better than structured queries at predicting relevance and user behavior. (Cook et al., 2017)

**Initiatives and Funding**

Future drivers and funders of informatics studies are those that are driving other veterinary and biomedical research today, the One Health movement and the human-animal bond. Both of these concepts come with greater responsibility for veterinarians in terms of increased regulatory oversight of disease detection, antibiotics, and controlled drug use. They also bring meaningful opportunities for veterinarians to participate in solving societal health problems. Both the One Health movement and the human-animal bond played a role in recent natural disasters, leading to a realization that disaster planning needs to incorporate animals for overall public safety. Animal travel and climate instability can result in spread of disease into non-endemic regions. Precision medicine incorporating geographic location, environmental conditions, physiologic data and genetic makeup provides growing opportunities for informatics.

Previous authors noted the difficulty veterinary schools have in forming multi-institutional and interdisciplinary collaborations needed to garner large grants. (Johnson et al., 2011) This is changing with examples such as the COHA Clinical and Translational Science Award initiative of 15 US Colleges of Veterinary Medicine. Other large informatics initiatives were funded with assistance from multiple organizations. For instance, ZIMS was partially funded through an Institute of Museum and Library Services (IMLS) grant (Species360) and the Morris Animal Foundation is one of the major funders of the Golden Retriever Lifetime Study. (Morris Animal Foundation) Other potential grant funding organizations are the Human Animal Bond Research Initiative (HABRI), which is interested in studies at the human-animal interface, as well as the Consortium of Universities for Global Health (CUGH), the Association for Public and Land Grant Universities, and the Association for Prevention Teaching and Research. Crowd sourcing
is another method of funding that has been successful for large-scale studies such as the Dog Aging Project at the University of Washington.

**Future and the Role of Libraries**

Since Talbot first wrote about artificial intelligence, machine learning neural networks have surpassed humans in pattern recognition, resulting in sophisticated systems being utilized in pathology and radiology. (Jha and Topol, 2016) An AI enabled urine sediment reader is routinely used and saving time in veterinary practices. (Idexx) An automated fecal parasite detector may be on the horizon. (Suzuki et al., 2013) Academic curriculum developers need to consider emerging technology as AI enabled systems match human clinical reasoning capability for intuitive pattern recognition. Expect to see more concrete examples of, and publications about, veterinary informatics and AI in the near future.

Artificial intelligence is also poised to disrupt literature searching as intelligent databases such as DeepLife from the Max Plank Institute, (Ernst et al., 2016) Microsoft Academic, (Microsoft) and Semantic Scholar from the Allen Institute(Allen Institute) emerge. Deep learning neural networks may answer a need in evidence-based medicine for more precise and rapid literature searching. (Del Fiol, 2018)

The future of academic libraries and access to biomedical literature may face its greatest hurdle in growing security issues. Hacking attempts inflict barriers to access on legitimate library users. Because existing library systems worldwide were already perceived as not meeting scientist’s needs, (Schwartz, 2013) and veterinary professionals lack of sustainable access to biomedical literature is a good example of this, many researchers and clinicians joined short-term #Icanhazpdf and Sci-hub movements rather than establish sustainable methods of access. The top five total uses of #icanhazpdf in 2015 came from the US, Great Britain, Germany, Canada and Australia. (Gardner and Gardner, 2015) A negative result for many libraries has been shrinking academic library budgets, lower perceived value of libraries, and growing imposed security measures that increase access steps for lawful users. A positive result has been a growing movement to publish open-access. The challenge now for libraries is in integrating open access resources, new models of peer-review, and formats and capabilities not traditionally collected by libraries into health informatics systems in a way that saves time, assesses quality, and adds value for the user. Libraries must now demonstrate that they meet and exceed the service offered
by more convenient and accessible free online tools; tools largely built using content and metadata supplied by libraries.

Security, privacy and confidentiality plays a greater role in clinical veterinary practice as well. The General Data Protection Regulation (GDPR) recently took effect in Europe and its broad scope incorporates veterinarians. Thanks to the GDPR, more companies worldwide are taking ethical steps to adopt best practice compliance. While this will result in needed directives to protect client data, it also places greater responsibility on institutions sponsoring or participating in large cohort big data studies. Growing interest in practice-based evidence requires more detailed informed consent at the time of treatment. (Mellanby, 2017) RCVS has taken a lead in this with their Ethics Review Panel headed by Mellanby. (Mellanby, 2017) Informed consent forms should be used, and reviewed for reading level and understanding, any time there are clinical trials of new medication, novel surgical techniques or medical devices, novel use of an existing medication, collection of superfluous tissue, environmental samples collected, questionnaires, and studies where data is needed beyond that collected as part of normal clinical practice (i.e. DNA). (Mellanby, 2017)

As groups like AVI and VetXML move forward in establishing interoperability of systems, there are simultaneous movements to integrate disparate data sources (EHR, social media, web searches, geospatial data, photos) through blockchain or bootstrapping. (Jones-Diette et al., 2016, Patterson and Grossman, 2017) This has already been done for problems like finding addresses in poorly mapped locations. (Jackson, 2018) As well, there have been studies looking at the ability to combine non-standardized human and animal disease information systems for disease surveillance. (Wendt et al., 2015)

As new information systems emerge, librarians can assume a role they have always filled, that of training new users and performing qualitative research, with the goal of improving the transition and user experience. As Nelson notes, “with newer fields such as informatics, qualitative and descriptive studies are needed first.” (Nelson and Staggers, 2018, p. 43) Teaching opportunities abound in veterinary institutions adapting to a world in which informatics plays a larger role. Implementation science is a growing field and one pertinent to all health care providers. The introduction of technology in the health care setting has reduced some types of error and bias, while introducing new unintended adverse consequences (UAC). (Coiera et al., 2016)
Of concern to librarians should be the knowledge that recent veterinary graduates rank the need for information evaluation and research skills as lower after they had been in practice than final year students. Those skills that ranked higher after time in practice were communication and decision-making. (Rhind et al., 2011) Librarians may not need to change what they are teaching in response to this, however they may need to reframe what they are teaching so that students understand its application to communication and decision-making. (Jansen et al., 2010, Kogan et al., 2010, Uy et al., 2014) Tierney sees a crucial need to introduce electronic documentation and systems training into veterinary communication training. (Tierney et al., 2013) In addition to improved communication, literature searching can serve as an introduction to metadata standards and controlled vocabulary that then informs clinical study outcomes and future study design. As well, the use of large-scale veterinary data repositories in classroom instruction may foster student interest in informatics.

Conclusion

In the past decade, we have seen a rise in precision medicine capability with genetic testing and wearable or environmental sensors able to contribute to “context specific” decision support. In veterinary medicine, these inform both individual animal and population health. At the same time, mobile and telehealth systems allow veterinarians to reach previously underserved and underrepresented populations. We have also seen veterinary medicine impacted by One Health and the growing need for health information exchange, both with human medicine and within veterinary medicine. Big data computing capabilities resulted in increased recognition of the need for standards and the ability to combine disparate data sources. Veterinary medicine now has actual established systems collecting practice and animal caregiver data. We also have tangible examples of artificial intelligence poised to provide decision support; sifting through large volumes of literature, patient information and environmental data to identify relevance beyond our capacity as humans.

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