Public Veterinary Medicine: Public Health

Evaluation of ProMED-mail as an electronic early warning system for emerging animal diseases: 1996 to 2004

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Objective—To identify emerging animal and zoonotic diseases and associated geographic distribution, disease agents, animal hosts, and seasonality of reporting in the Program for Monitoring Emerging Diseases (ProMED)-mail electronic early warning system.

Design—Retrospective study.

Sample Population—10,490 disease reports.

Procedures—Descriptive statistics were collated for all animal disease reports appearing on the ProMED-mail system from January 1, 1996, to December 31, 2004.

Results—Approximately 30% of reports concerned events in the United States; reports were next most common in the United Kingdom, Canada, Australia, Russia, and China. Rabies, bovine spongiform encephalopathy, and anthrax were reported consistently over the study period, whereas avian influenza, Ebola virus, and Hantavirus infection were reported frequently in approximately half of the study years. Reports concerning viral agents composed more than half of the postings. Humans affected by zoonotic disease accounted for a third of the subjects. Cattle were affected in 1,080 reports, and wildlife species were affected in 825 reports. For the 10,490 postings studied, there was a retraction rate of 0.01 and a correction rate of 0.02.

Conclusions and Clinical Relevance—ProMED-mail provided global coverage, but gaps in coverage for individual countries were detected. The value of a global electronic reporting system for monitoring emerging diseases over a 9-year period illustrated how new technologies can augment disease surveillance strategies. The number of animal and zoonotic diseases highlights the importance of animals in the study of emerging diseases. (*J Am Vet Med Assoc* 2006;229:1090–1099)

Abbreviations

ProMED	Program for Monitoring Emerging Diseases
SARS	Severe acute respiratory syndrome
WHO	World Health Organization
AHEAD	Animal Health and Emerging Animal Diseases
OIE	World Organization for Animal Health (Office International des Épizooties)

The ProMED-mail system began as the communication arm of the Federation of American Scientists' Program for Monitoring Emerging Diseases. As such, its core concepts were derived from the theory of emerging diseases. Joshua Lederberg, Stephen Morse, and their colleagues at the US National Academy of Sciences Institute of Medicine championed the idea that new demographic, economic, and political conditions around the globe increased the risk for emergence of new pathogens.[1] The best defense against the efficiency with which genetic selection turns previously unthreatening microbes into emergent pathogens is to husband resources carefully and track disease trends carefully.[1] It was postulated that use of better diagnostic laboratory tests, strengthening weakened components of public health infrastructure, improving surveillance, and increasing rapid global communication of disease outbreaks were the most appropriate responses to the increasing problem of emerging pathogens.

As the threat of emergent pathogens was dramatically being illustrated in the 1990s with outbreaks involving *Escherichia coli* O157:H7 in the northwest-

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ern United States and Ebola virus in Kitwit, Zaire, the use of electronic formats for global communication offered possibilities for improvement in response time and efficiency in combating these new diseases. By linking researchers, government officials, interested lay individuals, and journalists, ProMED-mail became an important means for outbreak reporting and follow-up discussions. It was open to all users, free of political constraints, and maintained by scientists who volunteered their time. Because of rigorous but creative management in the system's start-up phase that ensured that every item was reviewed by a qualified scientist, ProMED-mail evolved from a typical electronic information site into an independent, commonly consulted source of disease information.[2,3] By the mid-1990s, an eclectic mix of unregulated Web sites, the recently launched *Emerging Infectious Diseases* journal from the CDC, and ProMED-mail had revolutionalized the way information concerning infectious disease was disseminated. It was no longer possible for public health officials or others to restrict the flow of information to a "top-down" system of communication, even when it was thought that a unified animal or public health message was of imperative importance[2] or when such patterns of information flow were the policy of a politically authoritarian country, as was the case with dengue in Cuba, cholera in Indonesia, and SARS in China.[4,5]

Reports of disease outbreaks are posted on the Internet by various official and unofficial sources. The World Health Organization publishes frequent reports, some for a select group of subscribers, as well as the *Weekly Epidemiological Record* for public consumption. The OIE publishes *Disease Information* weekly, and also publishes periodic disease Alert Message reports. The Global Public Health Intelligence Network from Canada is a limited-subscription list that automatically searches the Internet for outbreak information, including items contained in media reports. Moreover, there are important national-level lists, including the *Morbidity and Mortality Weekly Report* from the CDC in the United States and British Public Health Laboratory Service's *Communicable Disease Report Weekly*.[6,7]

The ProMED-mail is an early warning and disease-reporting system, but it is not intended to be a comprehensive surveillance system. Comprehensive surveillance systems are iterative in the sense that they first collect, analyze, and use data to set policies and priorities and then measure the impact of new health policy, leading to another round of surveillance.[8] The ProMED system focuses on reporting disease and transmitting scientific information concerning disease control, thereby linking a wide variety of individuals on a global basis. Members of the worldwide subscriber base report local disease events, volunteers scan the World Wide Web for relevant media reports, and moderators glean electronically published information from official international and governmental sources such as those mentioned. The system also occasionally serves as a forum regarding laboratory techniques or epidemiologic data for scientists involved with ongoing outbreak investigations, as occurred with SARS in 2003 and West Nile virus in 1999.[7,9] The ProMED-mail database on emerging diseases was used formally only once before, to examine emergence of wildlife diseases from 1998 to 2000.[10]

The objective of the present report was to describe and compare the global patterns of animal diseases reported in the ProMED-mail system from 1996 (the inception of an animal disease list) through 2004 and to consider attributes of the system such as timeliness and accuracy.

Procedures

Development of the ProMED-mail system—The ProMED-mail was launched in August of 1994 with 40 e-mail subscribers. There was a steady increase in subscribership until after the Ebola virus outbreak in the spring of 1995, when ProMED-mail doubled in size to 2,000 subscribers. At present, ProMED-mail has approximately 30,000 subscribers in 164 countries.[11,12] The first e-mail reports were launched with the aid of the nonprofit foundation Satellife,[a] and since 1999, the International Society for Infectious Diseases has hosted the service. The most important contribution made by Satellife was allowing the exchange of e-mails 2 or 3 times/d as its medical communications satellite circled the earth in a low-level polar orbit.[6] The ProMED-mail has now evolved to take full advantage of the Internet by offering the same information on emerging diseases via e-mail and a Web site. The system adds value to the information that it posts by ensuring that all items are read and subject to culling by a specialist moderator and at least 1 editor.[4,5,7] Background commentary is provided by moderators, and all reports are archived in a searchable database on the Web site.

From its inception, ProMED-mail monitored emerging diseases in animals and plants as well as in humans, incorporating the 1 medicine concept. The developers of the system understood that the effects of animal and plant diseases are not limited to animal and plant populations alone but also have substantial impacts on humans. Schwabe[13] provided historical examples of such indirect but severely disruptive impacts using the nonzoonotic, putatively animal disease rinderpest as an example, in Europe first and then in Africa in the late 1800s. The Irish potato famine in the middle of the 19th century is an example of the same kind of human impact from a plant disease. Because 70% to 90% of newly emerging diseases in humans are zoonotic, 4 of the 14 specialist moderators on the site are veterinarians.[7,14] Substantial ProMED-mail coverage has been devoted to strictly animal diseases such as foot-and-mouth disease.

Production of a ProMED-mail disease report—Originating from a variety of sources, including government health departments, international organizations, subscribers' professional or personal observations, and the media, dozens of reports are submitted to ProMED-mail daily. The 22 staff members from 9 countries collaborate to synthesize incoming data into useful reports. Madoff[7] provided a description of information flow at ProMED-mail (**Figure 1**). An incoming

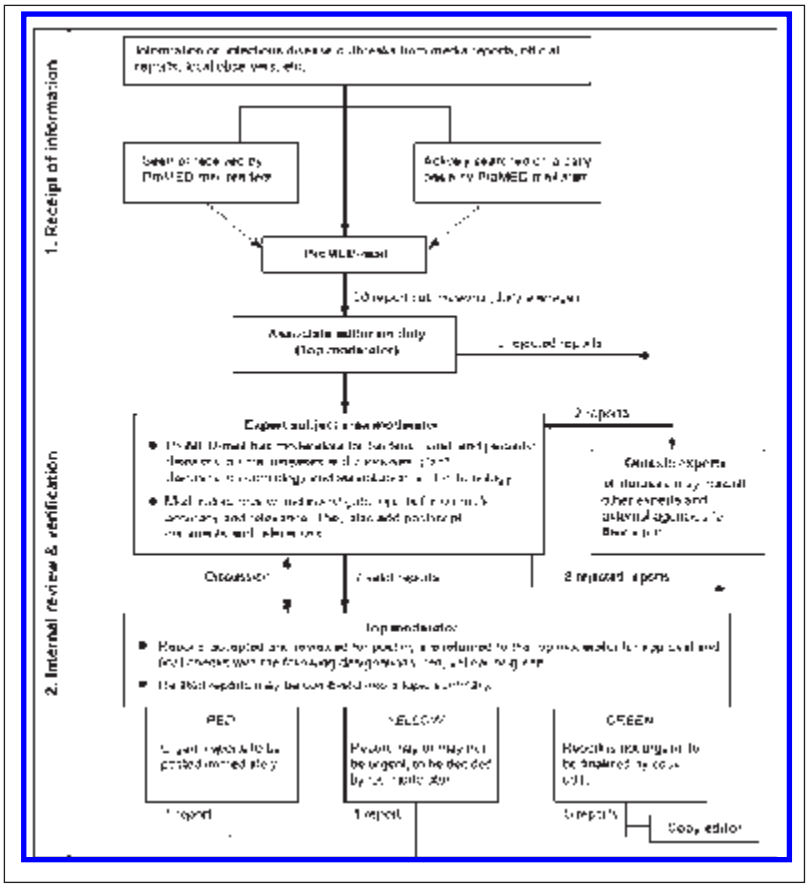

Figure 1—Schematic diagram depicting the flow of information in the ProMED-mail electronic disease-reporting system.

report is first received by the top moderator on duty (ie, an expert in infectious disease, public health, or epidemiology), who may reject the information immediately or choose to send it to an expert subject moderator for further review. Subject moderators include 4 experts in veterinary and zoonotic diseases; 2 experts in viral diseases; and 1 each in bacterial disease, parasitic disease, plant disease, epidemiology and surveillance, and medical entomology. The subject moderator assesses accuracy of the data, edits the report for clarity, supplies references, and often includes a brief commentary highlighting the importance of the new information. The edited report returns to the top moderator, who audits the work of the subject moderator and assigns 1 of 3 levels of urgency to the report. A ProMED-mail green report is of lowest importance and normally flows through the system in 24 hours. After the expert moderator's contribution, a professional copy editor formats the piece, edits for grammar and consistency, and flags any questions before returning the piece to the top moderator. If coded yellow, a report undergoes expedited review. Reports with the greatest urgency may be coded red and bypass portions of the review process altogether. Subscribers may choose from a variety of specialized lists from which to receive mail and may also view archived information at the ProMED-mail Web site.

Subscriber base—Subscribers contribute much of the material that appears on ProMED-mail. In 1997, the first year for which data are available, the system had 10,268 subscribers from 124 countries, 4,052 (39.4%) of whom were outside the United States, as indicated by the e-mail addresses. At the end of the final year of the study period (2004), there were 29,458 users from 164 countries, 10,644 (36.1%) of whom had e-mail addresses outside of the United States. For the 18,814 subscribers in the United States, 7,032 (37.4%) had a commercial e-mail address (ie, ending in .com), 3,599 (19.1%) originated from educational institutions (e-mail address ending in .edu), 2,062 (11%) were federal government workers (e-mail address ending in .gov), 1,667 (8.9%) were state or local government workers (e-mail address ending in .us), 1,571 (8.4%) had nonprofit organization–based addresses (e-mail address ending in .org), and 1,057 (5.6%) used military addresses (e-mail address ending in .mil). Another 1,816 (9.7%) subscribers had US e-mail addresses but did not fit into any of the above categories. The second largest group of subscribers was from Australia (n = 1,428), followed by subscribers from Canada (1,394), the United Kingdom (937), Germany (532), and Brazil (465).

Data analysis—Data were collected from the AHEAD specialized list of ProMED-mail, which provides information on such animal and zoonotic diseases as foot-and-mouth disease, avian influenza, and anthrax. The AHEAD specialized list was launched on December 15, 1995, approximately 15 months after ProMED-mail began disease-reporting activities. The data cover the first 9 years of AHEAD list activity (from January 1, 1996, to December 31, 2004). Data were obtained by requesting the subject line and associated archive number from the ProMED-mail archives. Subject headings are developed by the moderators, are limited to 80 characters, and generally follow a specific format and order: disease or condition name, species of animals affected, and geographic location. From each posting, the subject, disease name (if any), species, geographic location, and date were extracted and exported into a file.[b] Not all postings contained information in all those categories, and some postings had more than 1 piece of information in a given category. For example, species might be designated "porcine, bovine"; countries might be "Vietnam, China"; and species, country, or disease name are frequently omitted from the title. If more than 1 species or country was mentioned in the title, it was counted 1 time for each species or country mentioned. For this reason, different numbers of postings are denominators for different kinds of analyses. When information was not apparent from the title, the

senior author (PC) reviewed the body of the posting and provided the necessary information.

From the data in the subject line of each report posting, groupings were determined according to type of disease agent (eg, virus, bacteria, or prion), species of animals affected, and location of disease occurrence as determined by the country cited in the subject line. It was also noted whether a report posting was part of a discussion thread, a request for further information, or a correction and whether it originated from OIE. Reports were classified into categories of collegial information (such as conference announcements and discussion of historical events) or disease information. Information pertaining to whether the disease subject was a former OIE list A or B disease was also recorded.

Data analysis was limited to descriptive statistics. Tests of significance were considered to be beyond the scope of this study given its objective of providing a description of the electronic reporting of emerging diseases. A commercially available software program[b] was used for descriptive statistics and cross-classifications for the number of report postings by month, year, disease agent, geographic location, and target species. The ProMED-mail system and OIE were compared for timeliness of reporting by assessing the number of days that elapsed between the time of posting of an item on 1 system and the item's posting on the other system. Reports for which the times of reporting on the 2 systems were < 1 day apart were considered to be no different because time zone differences could have accounted for the different dates of publication.

Results

Geographic origin of disease reports—Reports of disease in 191 countries were published on the ProMED-mail AHEAD list during the study period. Not surprisingly given the subscriber base, the United States was the location specified for the most disease reports, accounting for slightly < 30% (n = 2,629) of the 9,192 disease-related postings that contained a geographic reference. Diseases in the United Kingdom accounted for the second largest number (n = 728 [8%]) of postings in that category; Canada, Australia, Russia, and China were also frequent sites of disease reports, with 428 (4.7%), 323 (3.5%), 247 (2.7%), and 215 (2.3%) reports, respectively (**Figure 2**). In South America, disease reports from Brazil (n = 184 [2.0%]) and Argentina (80 [0.9%]) were the most frequent. In Africa, South Africa (n = 147 [1.6%]), Uganda (117 [1.3%]), and the Democratic Republic of the Congo (115 [1.3%]) were the most frequent sites of origin of disease reports. In Asia, Malaysia (n = 177 [1.9%]), India (171 [1.9%]), and Japan (153 [1.7%]) were the most frequent report locations. The Middle East generally had few reports of disease, with the exception of Israel (n = 76 [0.8%]) and Saudi Arabia (72 [0.8%]); the countries with the next most frequent disease reports were Iraq (20 [0.2%]) and Iran (15 [0.2%]). In Europe, frequent locations for disease reports included France (n = 153 [1.7%]), The Netherlands (109 [1.2%]), and Germany (102 [1.1%]). Only Suriname, North Korea, and Greenland had no reports of disease during the study period.

The greatest numbers of disease reports were consistently associated geographically with the United States, ranging from 107 reports in 1996 to 396 reports in 2002. The United Kingdom accounted for the second greatest number of postings in all years except 1999 and 2003, when Malaysia (n = 113) and Canada (83), respectively, were the second most frequent locations for disease reports (**Table 1**). Except for 1996, Canada was 1 of the 5 most frequently cited locations

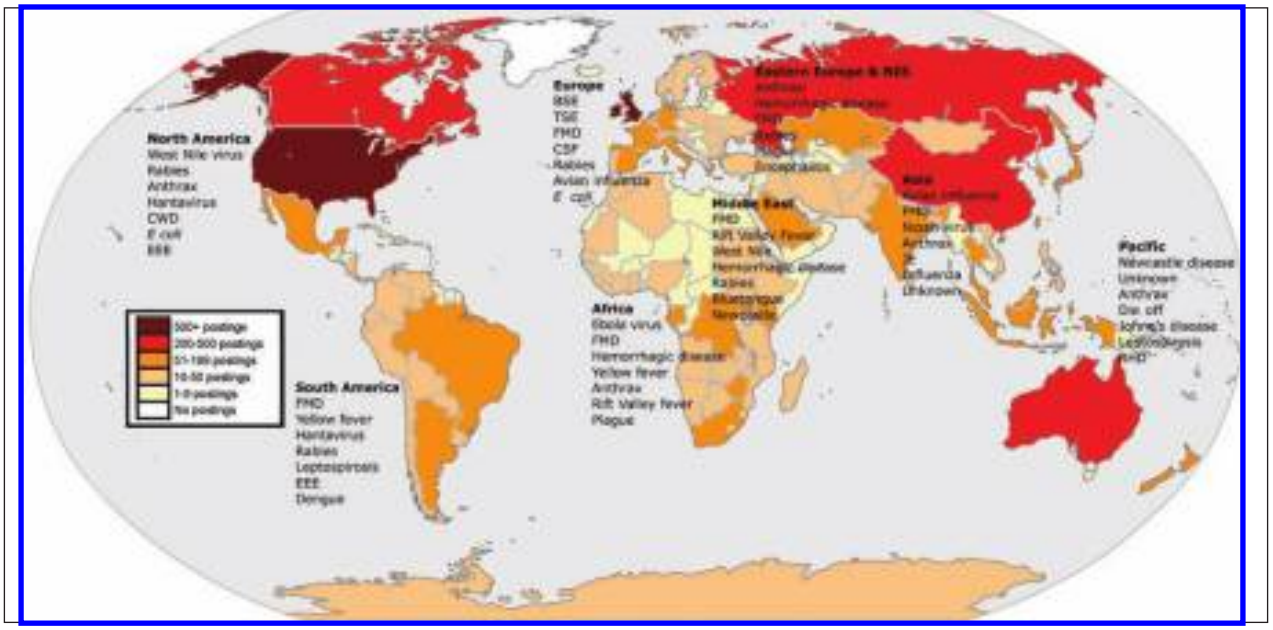

Figure 2—Distribution and frequency of reports by country, and the 7 most frequently reported diseases by continent or geographic region for ProMED-mail AHEAD postings from 1996 to 2004. NIS = Newly Independent States. CWD = Chronic wasting disease. EEE = Eastern equine encephalitis. BSE = Bovine spongiform encephalopathy. TSE = Transmissible spongiform encephalopathy. FMD = Foot-and-mouth disease. CSF = Classical swine fever. JE = Japanese encephalitis. RHD = Rabbit hemorrhagic disease.

Table 1—Summary of the 10 countries or geographic locations cited most frequently in disease reports on the ProMED-mail AHEAD list by year from 1996 to 2004.

Year	No. of postings	Year	No. of postings	Year	No. of postings
1996		**1997**		**1998**	
USA	107	USA	239	USA	306
UK	22	UK	80	UK	99
Australia	14	Australia	50	Australia	73
South Africa	13	Canada	35	Canada	49
France	9	China	25	France	29
The Netherlands	9	Congo DR	22	China	28
Balkans	8	Europe	21	Kenya	27
Canada	7	Germany	18	Russia	26
Japan	7	Japan	18	East Africa	17
Africa	6	New Zealand	18	Indonesia	16
Total	**202**	**Total**	**526**	**Total**	**670**
1999*		**2000**		**2001**	
USA	306	USA	338	USA	355
Malaysia	113	UK	83	UK	150
Russia	53	Uganda	59	Canada	53
Canada	49	Australia	43	Brazil	36
UK	40	Canada	41	India	25
Australia	36	Russia	31	Kenya	21
China	23	Saudi Arabia	30	Argentina	20
France	23	India	27	Gabon	20
Belgium	18	South Africa	27	Germany	20
Brazil	18	France	26	Russia	20
India	18	**Total**	**705**	**Total**	**720**
Total	**697**				
2002		**2003**		**2004**	
USA	396	USA	339	USA	310
UK	80	Canada	83	Asia	183
Canada	52	UK	62	UK	71
Australia	31	Congo DR	41	Canada	59
Gabon	31	Netherlands	39	Russia	56
India	21	China	35	China	54
South Korea	21	Russia	35	India	38
Japan	18	Brazil	33	Australia	37
China	17	India	25	South Africa	36
Israel	17	Mexico	23	Brazil	35
Total	**684**	**Total**	**715**	**Total**	**879**

*Eleven entries were included because 3 countries had the same number of postings.
UK = United Kingdom. DR = Democratic Republic.

for reports in all years, and Australia was in that group in the 1996-to-1998 interval and in 2000 and 2002. Russia and France were in the 5 most frequently cited locations for 2 years, whereas 8 other countries appeared in the top 5 reporting countries for a single year. China was the fifth most frequent location of disease reports once and was the sixth most frequent location 3 times during the study period.

Most frequently reported diseases—Rabies was among the 10 most frequently cited diseases reported in every year of the study and was the most commonly reported disease in 1997 and 1999. Avian influenza was the most reported disease in 2004 and second most reported disease in 2003; the disease made the list of top 10 reported diseases 3 other times—in 2002 and in 1997 and 1998 under the title Influenza. Several diseases were reported frequently for a period and then declined in frequency of postings; such was the case with salmonellosis, which was reported only in the first 3 years of the study (**Table 2**).

There were no seasonal or other types of periodicity when numbers of disease and information postings were plotted by month. In 1996, the number of postings reported per month ranged from 36 in February to 102 in April. After that, the number of postings ranged from 199 in August of 1997 to 63 in December of 1999. Spikes in the number reported occurred in March of 2001 (n = 177), September of 1997 (171), January of 2004 (170), and both May and June of 1997 (167 each). In some instances, a high number of postings resulted from a single disease outbreak, whereas in other instances, a high number of postings resulted from several outbreaks. In other instances, the reason for the increased number of postings could not easily be identified. For example, in March of 2001, 106 reports of foot-and-mouth disease concerning the outbreaks in the United Kingdom and Netherlands accounted for most of the postings. However, in September of 1997, no single disease accounted for the increase in the number of reports that month.

A change in the categories of diseases that were posted over time was also observed. In 1996, there were approximately equal numbers of disease information and collegial information postings. For example, collegial information postings comprised 38.8% of postings in March of 1996 and 46.6% in November of 1996. After the beginning of 1997, collegial information postings gradually decreased in number and comprised < 10% of the postings. Beginning in 1999, a noticeable increase in the number of collegial information items usually occurred in November and

Table 2—The 10 most frequently reported diseases by year on the ProMED-mail AHEAD list from 1996 to 2004.

Year	No. of postings	Year	No. of postings	Year	No. of postings
1996		**1997**		**1998***	
BSE	71	Rabies	98	BSE	108
TSE	61	BSE	67	Rabies	55
Die off	27	TSE	67	Die off	46
Unknown	24	*Escherichia coli*	58	Salmonellosis	42
Salmonellosis	18	Influenza	41	Anthrax	41
Rabies	15	Hantavirus	40	Leptospirosis	36
Ebola	12	Anthrax	37	RVF	36
RHD	11	Foodborne	33	TSE	36
FMD	10	Salmonellosis	33	Influenza	32
Hantavirus	10	Die off	27	Newcastle	27
Total	**259**	**Total**	**501**	Plague	27
				Total	**486**
1999		**2000**		**2001**	
Rabies	80	West Nile	148	FMD	252
Nipah virus	73	FMD	91	West Nile	174
Hemorrhagic disease	53	BSE	68	Anthrax	137
West Nile	52	Rabies	65	BSE	69
BSE	50	Ebola	63	Hemorrhagic disease	67
FMD	48	Anthrax	53	Yellow fever	44
Hendra virus	37	Hemorrhagic disease	51	Rabies	40
Anthrax	36	Hantavirus	43	TSE	39
JE	35	RVF	34	Ebola	32
Hantavirus	34	TSE	31	CSF	29
Total	**498**	**Total**	**647**	**Total**	**779**
2002		**2003**		**2004**	
West Nile	215	West Nile	130	AI	355
FMD	72	AI	85	Rabies	79
Anthrax	61	FMD	62	Anthrax	78
BSE	53	BSE	56	FMD	75
CWD	45	Newcastle	52	Unknown	70
Rabies	39	Yellow fever	51	West Nile	58
Ebola	36	Rabies	44	BSE	37
TSE	36	Anthrax	38	Yellow fever	30
Hantavirus	33	Ebola	38	Die off	28
AI	30	EEE	28	Hemorrhagic disease	27
Total	**620**	**Total**	**584**	**Total**	**837**

*Eleven entries were included because 2 diseases had the same number of postings.
BSE = Bovine spongiform encephalopathy. TSE = Transmissible spongiform encephalopathy. RHD = Rabbit hemorrhagic disease. FMD = Foot-and-mouth disease. RVF = Rift Valley fever. JE = Japanese encephalitis. Hemorrhagic disease = Hemorrhagic disease of unknown origin. CSF = Classical swine fever. CWD = Chronic wasting disease. AI = Avian influenza. EEE = Eastern equine encephalitis.

December of each year because of ProMED-mail's annual fundraising event, the Internet-a-thon, and other year-end informational items. From 1996 to 2004, 2,085 collegial information items and 10,490 disease information items were posted.

Disease agents and animals affected—Viruses (n = 5,432) accounted for more than half of the 10,069 postings in which the reported disease was ascribed to an agent. Bacteria were the next most numerous disease agent category (n = 1,997), and prions were third, reported in slightly more than 1,000 postings. Not surprisingly, given the emerging disease focus of ProMED-mail AHEAD and the emphasis on selective reporting, parasites (n = 161), other (127), fungi (39), and external parasites (26) made up much smaller proportions of postings.

The most frequently cited animal category in the ProMED-mail AHEAD database was humans, with zoonotic disease reported in 2,210 postings (**Table 3**). Cattle was the next most frequently cited animal category with 1,080 postings; wildlife followed with 825 postings, and avian species was fourth with 545 report postings. Among the other domestic animals that typically receive veterinary services, equids were cited most often (n = 422); swine were next most frequently cited (325); and poultry (172), dogs (167), cats (57), and unspecified pets (40) were cited in fewer report postings.

Length of report threads—The ProMED-mail reports were often sequential in nature, as information regarding a particular outbreak was received and transmitted over the course of the outbreak. The largest category of postings in this study was comprised of single items that were not followed up with additional information. However, reports pertaining to outbreaks in which a substantial threat was posed to animal or human health were often strung together in threads or sequentially numbered reports on the same outbreak. Moderators decided when to start new threads on the basis of factors such as changes in geography, host, agent identification, and new calendar year. Lengths of ProMED-mail AHEAD posting threads that reached or exceeded 20 postings were summarized (**Table 4**). The longest thread was related to the worldwide SARS outbreak in 2003 (n = 191 postings); avian influenza in Eastern Asia in 2004 was next longest (156); and foot-

and-mouth disease in the United Kingdom in 2001 was the third longest report thread (73). Approximately a quarter of the outbreaks that generated the longest report threads were associated with West Nile virus. Most (n = 3,354) threads were composed of single reports, whereas 953 threads were 2 reports long and 368 threads were 3 reports long.

Timeliness of report postings—There were many differences in scope, purpose, and methodology between reports from the largest official outlet of world animal health information (the OIE *Disease Information* weekly reports) and those on the ProMED-mail AHEAD system. From January 1, 2002, to December 31, 2004 (the time period for which reports from the OIE Web site could be downloaded directly), 121 reports of former OIE list A diseases (defined as having very serious and rapid spread, irrespective of national borders) and 44 list B diseases (defined as having socioeconomic or public health importance with international trade implications) were circulated by both ProMED-mail AHEAD and the OIE *Disease Information* weekly report (via the OIE Web site). For the 121 OIE list A disease incidents reported by both sources, ProMED-mail published 6 reports between 1 and 2 weeks earlier than the OIE *Disease Information* weekly reports, whereas 2 OIE reports were published 1 to 2 weeks earlier than ProMED-mail. The OIE published 38 reports 2 to 7 days earlier than they were published on the ProMED-mail AHEAD list. Conversely, ProMED-mail had 29 reports that were posted 2 to 7 days earlier than they were posted on the OIE Web site.

For diseases on the former OIE list A, 117 report postings were carried only on ProMED-mail and not on the OIE list, whereas 44 reports were carried only on OIE *Disease Information* weekly reports. During the same 2-year period for OIE list B diseases, 321 items were carried only on ProMED-mail, whereas 15 items were published only on the OIE *Disease Information* Web site.

Special designation postings—Because of the inherent iterative and interactive nature of the ProMED-mail electronic information format, postings often contained limiting designations that marked the report as belonging to the suspected, confirmed, or other categories. The low numbers of those types of reports posted per year indicated stability over time. The exception was the number of suspected postings, which increased every year, markedly so beginning in 2001. The number of requests for information postings was greatest in 1997 (n = 62) and lowest in 2002 (16). There were 104 report postings designated not, which indicated that the disease that had previously been sus-

Table 3—Number of postings by animal category in ProMED-mail AHEAD postings from 1996 to 2004.

Animal category	No.
Zoonotic (affecting humans)	2,210
Bovine*	1,080
Wildlife†	825
Avian‡	545
Equine	422
Livestock: sheep, goats§	354
Swine	325
Fish‖	216
Poultry	172
Dogs¶	167
Marine mammals	102
Shellfish#	100
Reptiles & amphibians	77
Zoo animals	72
Cats¶	57
Other**	31
Pets††	40
Livestock, other‡‡	7
Total	**6,802**

*Domestic cattle, buffalo, yaks, and wild bovids. †Only wild prairie dogs. ‡Wild and domestic waterfowl and pet birds. §Sheep, goats, and other species of nondesignated livestock. ‖Farmed fish except shellfish. ¶Both domestic and feral dogs or cats. #Coral and starfish. **Algae, insects, rats, laboratory mice, field mice, and guinea pigs. ††Generic designation of pets. Species was not specified, including prairie dogs associated with a monkey pox outbreak in the United States. ‡‡Includes camels, water buffaloes, llamas, alpacas, and captive deer.

Table 4—Report posting thread length and subject of discussion for report posting threads 20 or more reports in length on the ProMED-mail AHEAD list from 1996 to 2004.

Thread length	No. of threads	Subject
20	1	Hemorrhagic disease—Kenya
21	1	Hendralike virus—Malaysia
22	2	Nipah virus—Malaysia; Ebola virus—Gabon: new outbreak
23	1	Avian influenza—Canada
24	1	Avian influenza—The Netherlands
26	1	Ebola hemorrhagic fever—Gabon and Democratic Republic of the Congo
27	1	West Nile virus—Canada
28	1	Bovine spongiform encephalopathy update 2001—worldwide
29	1	West Nile virus update 2004—western hemisphere
33	1	Ebola hemorrhagic fever—Democratic Republic of the Congo
34	2	West Nile virus surveillance 2001—United States; *E coli* O157—Japan
35	1	West Nile virus update 2002—United States
36	1	West Nile virus update 2003—United States
38	1	Influenza—bird-to-human—China (Hong Kong)
41	1	Anthrax—United States
53	1	Avian influenza, human—eastern Asia
54	1	West Nile virus surveillance—United States
57	2	Ebola hemorrhagic fever—Uganda; Bovine spongiform encephalopathy—UK
73	1	Foot-and-mouth disease—UK
156	1	Avian influenza—eastern Asia
191	1	SARS—worldwide

pected (or even announced) was later ruled out as the diagnosis. There were 199 correction postings over the study period. Corrections were issued for a variety of items, including spelling, inappropriate terminology, agent name, location, and number of cases. For the 10,490 report postings studied, there was a retraction (ie, not) rate of 0.01 and a correction rate of 0.02.

Discussion

The ProMED-mail system's subscriber base in 164 countries and disease postings originating from all but 3 countries in the world enable extensive global coverage. However, there were obvious gaps in reports from certain countries or regions, some of which were the source of just 1 to 9 postings over the 9-year study period. Those regions included countries in the Sahara Desert region from Mali to Egypt, areas of the Middle East, and some parts of eastern Europe. Countries in southern Africa and in parts of equatorial Africa had relatively high numbers of disease report postings, but it is possible that special effort may have been required to post reports in east and west Africa, particularly in francophone Africa. One method of increasing geographic distribution is to have access to language-competent moderators or Web searchers in key countries, as ProMED-mail does in Brazil, Spanish-speaking countries, and Russian-speaking areas of the former Soviet Union. Another ProMED-mail initiative is the Mekong Basin Disease Surveillance program, a project designed to have Vietnam, Thailand, Cambodia, Myanmar, Laos, and the Yunan province of China institute an electronic emerging disease communication system modeled after ProMED-mail but operated in a way that meets regional needs. The substantial and continued proliferation of Internet access in these regions may provide a sturdy foundation for regional initiatives. It would be useful to explore the extent to which language represents an obstacle to reporting in South America, the Middle East, and eastern Europe.

The United States was the most frequently cited location for reports in every year of the study, with approximately 2 to 5 times the number of reports that pertained to the next most frequent country, the United Kingdom, in all but 3 years. To what extent this represented actual disease occurrence or whether some form of reporting bias existed could not be determined from this study. The data on thread length indicated that certain diseases received extensive coverage, in that 86 disease subjects had thread lengths of at least 10 reports and 24 had 20 or more. The cumulative effect of those reports can be extensive and comprehensive because a long thread is likely to contain comments from experts, reference to relevant research studies, and summaries of official epidemiologic and diagnostic investigations.

The pattern of occurrence for individual diseases is varied and cannot easily be explained, even if an investigator has knowledge of the typical epidemiologic features of the disease. The ProMED-mail data function at the macro level using global population data. At this level of granularity, it may be very difficult to predict or explain which disease will occur most frequently from year to year. However, for some diseases, such as rabies, foot-and-mouth disease, bovine spongiform encephalopathy, and anthrax, disease reports were posted with regularity and at high numbers over the study period. With rabies, for example, the fact that it was the subject of regular reportings was not surprising because rabies consistently results in over 55,000 human deaths annually worldwide. Other diseases, such as Nipah virus and rabbit hemorrhagic disease, appeared frequently in postings in particular years and then decreased in number.

Although humans were the species most frequently involved in disease postings, they were disease targets in only a third of the postings for which a species was specified. Bovids were the next most common target species, and wildlife and avian species ranked third and fourth, respectively. Reports about wildlife species often involved undiagnosed die-offs, as well as known diseases such as rabies or tuberculosis. Avians included wild birds and a small number of pet birds. Poultry was categorized separately and ranked ninth in the frequency of target species, a figure that was much lower than was expected given the number of poultry worldwide. Viruses were cited in disease reports more frequently than all other specified disease agents combined.

Comparison of OIE and ProMED-mail for characteristics of timeliness in disease reporting should be approached with caution. The 2 reporting systems are very different, with OIE functioning largely as a passive surveillance system that is dependent on official reports from its 170 member countries, whereas ProMED-mail acts as an independent early warning system. The times assessed for OIE reporting in the present report were biased toward slower reporting because taking into account OIE's more urgent Alert Message disease notification system would have been too labor intensive for this project. The OIE Alert Message system publishes outbreak information at the time a notice is received, rather than in weekly intervals, as is done with the OIE *Disease Information* system (from which the data used in this study were extracted). Moreover, the OIE data available for use in the present study did not cover the entire study period, only the 2 most recent years. The OIE has made substantial progress in implementing effective, rapid disease-reporting systems over the last several years and it is possible that inclusion of data for the whole period may have yielded different trends.

Special designation postings included those in requests for information and suspected categories, which together comprised 60% of the special designation report postings. There were only one third the number of confirmation as suspected postings, although that relationship does not always require that a confirmation be issued for a previous corresponding suspected report posting. A dramatic increase in the number of suspected postings was observed beginning in 2001, although the reason for this finding was not clear.

The present analysis had drawbacks typical of those inherent in all retrospective studies. There was little control over the type of data that could be collected, a fact that was mitigated by the fact that all

moderators used the same rubric for composing the posting titles and titles were checked for accuracy before distribution. Because data were extracted from the posting titles, data were at least standardized across all ProMED-mail moderators. A second concern pertaining to retrospective studies is the inability to control for factors that may lead to bias. The most serious source of bias in this study would be reporting bias, in which certain diseases are more frequently reported than others. This is likely to have had some effect in regard to the ProMED-mail system because we chose to report only emerging diseases, not all diseases; hence, data should be interpreted with the potential for reporting bias in mind. The bias would most likely be toward large outbreaks with high mortality rates and against endemic diseases like campylobacteriosis or leptospirosis, unless the latter were large in scope or had unusual epidemiologic features.

The results of this study underscored the distinction between a surveillance system for infectious diseases and an electronic, early warning, emerging disease–reporting system such as ProMED-mail. Under ideal conditions, surveillance systems should be founded on systematic local data collection so that the information generated is comparable from year to year and from place to place. The ProMED-mail system operates on a global and local basis so that subscribers in the United States, for example, may describe a local outbreak of *E coli* O157 at a restaurant in Wisconsin and may also circulate information about Ebola virus in Uganda. Determination of exact quantitative relationships between characteristics of the subscriber base and the location and type of posted reports was beyond the scope of this report; however, the relationship is not causal, indicated by the fact that in the last year of the study, the subscriber base in the United States accounted for 63.8% of all subscribers, yet the United States was cited as the outbreak location in only 310 of the 1,519 reports in which a geographic location was specified. Moderator decisions about validity and importance of reports, news media choices about diseases or countries of greatest interest, transparency of official sources, and other unknown factors affect what emerging disease information actually appears in ProMED-mail.

Nevertheless, important animal and public health events received consistent, comprehensive coverage. For example, coverage of the SARS outbreak started with a single posting from an individual who had received information about hospitalization in Guangdong, China. His report was vetted and eventually posted as "Pneumonia—China (Guangdong): request for information." One month and 6 posted reports later, a similar syndrome was recognized in humans in Hanoi, Vietnam; in the commentary to that report, the moderator wondered how "the WHO in Hanoi could be sure the disease would not spread" to the general population. The WHO issued a global alert for "atypical pneumonia" the next day; ProMED-mail followed with 196 sequential reports on SARS in 2003 alone.[7] Similar early warning scenarios could be described for many other important outbreaks, including the West Nile virus outbreak in New York City in 1999 and the avian influenza outbreak in Hong Kong in 1997.

The ProMED-mail contributors are a diverse population that includes academicians, government officials, members of the news media, and interested lay individuals operating in nearly all of the world's countries. The eclectic nature of the community of those who are interested in emerging diseases is simultaneously the greatest strength and most serious weakness of any Internet-based reporting system. The strength aspect arises from the fact that the informative power of the Internet carries thousands of animal or public health reports, official press releases, and news articles daily. Secondly, the subscriber base is global, consisting of approximately 30,000 individuals, many of whom are in key knowledge positions in the emerging disease community. Also, the iterative nature (ie, posting requests for information, receiving information from official and unofficial sources, and updating information as an outbreak continues) of the ProMED-mail system substantially enhances the scope and validity of its postings. Finally, periodic moderator commentaries add perspective.

Weaknesses include the potential loss of accuracy when scientific information gets lost in translation. Because items from the news media are included, the inherent nature of an early warning, emerging disease–reporting system necessitates that some items will be published before full information regarding the event is available (although many reports of diseases lacking sufficient or credible information are rejected by moderators). Although ProMED-mail is strengthened by the independence of its subscriber base and moderators, it is weakened by a perpetual lack of adequate funding because it is not owned by an individual or entity and is essentially operated on a volunteer basis.

The volume of postings regarding zoonoses and animal diseases underscores the role that animals have played in emerging diseases during the 9-year period covered by this study. Postings on the AHEAD specialized list represented approximately 65% of the information flow on ProMED-mail. Such a percentage would not have surprised early adherents to the axiom of emerging diseases in which economic, political, demographic, and cultural conditions interact to create new disease ecologies and interfaces among humans, domestic animals, and wildlife. Changing interfaces among those groups resulted in new foodborne disease outbreaks in the United States, Ebola hemorrhagic fever in Africa, foot-and-mouth disease and bovine spongiform encephalopathy in Europe, and SARS and H5N1 avian influenza in Asia. Continuously updated information on all of those events was disseminated by ProMED-mail. In a world in which the struggle with emerging diseases is likely to continue, knowledge is power.

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