Table 1.6: Mortality from cholera in London, July 8 to August 26, 1854, related to source of individual water supply in three groups of districts (from Snow, 1855)

Group of districts with water supplied by	*Water supply of individual houses*	*Population, 1851 census*	*Deaths from cholera*	*Cholera death rate per 1000 population*
Southwark and Vauxhall company	Southwark and Vauxhall company	167,654**	738	4.4
Lambeth company	Lambeth company	19,133**	4	0.2
Both companies	Southwark and Vauxhall company	98,862	419	4.2
	Lambeth company	154,615	80	0.5
Rest of London		1,921,972	1,422	0.7

** Overestimated by a small amount, since this figure includes population with no water supply.

Pierre Louis (1787–1872)
Introduced the 'numerical method' in medicine

Rudolf Virchow (1821–1902)
'The founder of (microscopic) cellular pathology'
'A believer in role of social science in medicine'

different treatments, the best method would be to administer them in different wards of large hospitals to which access of patients would be on a strict rotation basis without any possibility of choice on the part of the physicians. The outcome of each treatment would then be carefully recorded and counted and the whole process, as well as the interpretation of the results identifying the superior treatment (if any), would be strictly monitored and reported by a steering committee.[10]

German scientist **Rudolf Virchow (1821–1902)** work in pathology is regarded as a cornerstone of modern medicine. He believed that 'medicine is a social science'. At the International Congress of Statistics in 1855, Rudolf Virchow stated the form of the bulletin indicated by Mr Farr can be recommended from the practical and medical point of view, because it contains one column for the disease, and another for the consequences of the diseases that have been the immediate cause of death; for it is one of the most important aims of statistics to know not only the direct causes of death but also the indirect ones, i.e. the pathological state which produces the truly lethal alterations. The mechanism itself of death is of interest for practical statistics only in the case of crime, or of a lesion due to violence, or of accident.[11]

One can clearly recognize here the basic concept and structure of current death certification, separating underlying causes from proximate causes, as well as the separate study—descriptive) and motivate explorer for further study (analytical and experimental) the disease or health event in question.

Any kind of study will be incomplete if it does not describe the what, who, where, when, and why/how of a situation/disease or health event, e.g.

i.	What is the event?	(The problem)
ii.	Where did it happen?	(Place distribution)
iii.	When did it happen?	(Time distribution)
iv.	Who are affected?	(Person distribution)
v.	Why did it happen?	(Causes and risk factors)
vi.	How did it happen?	(Mode of transmission)

Making Comparisons

Epidemiology is basically focusing its perspective on groups or populations rather than individuals. Various tools are needed to compare different characteristics relating to disease occurrence between populations in relation to different time periods, different places or different groups of persons. The comparison of groups may be done in terms of morbidity, mortality, disability, fertility, etc. the comparison of morbidity or mortality in populations with and without a certain exposure or the comparison of exposure between diseased subjects and a control group. Inclusion of an appropriate reference group (non-exposed or non-diseased) for comparison with the group of interest is a condition for causal inference.

One of the first considerations before making comparisons is to ensure what is known as 'comparability' between the study and control groups. In other words, both the groups should be similar so that "like can be compared with like". For facts to be comparable, they must be accurate, and they must be gathered in a uniform way. The comparability can be best achieved by randomization or matching. Another alternative is standardization which usually has a limited application to a few characteristics such as age, sex and parity.

Making Decisions

Epidemiological reasoning and decision making consists of three major steps. First, a statistical association between an explanatory characteristic (exposure) and the outcome of interest (disease) is established.

Then, from the pattern of the association a hypothetical (biological) inference about the disease mechanism is formulated that can be refuted or confirmed by subsequent studies. Finally, when a plausible conjecture about the causal factor(s) leading to the outcome has been established then decisions are taken.

In practice, these three major steps are interwoven in an iterative process of hypothesis generation by descriptive and exploratory studies, statistical confirmation of the presumed association by analytical studies and, if feasible, implementation and evaluation of intervention activities, i.e. experimental studies. Based on results/finding, actions/programs are designed and decided to implement (if beneficial) to population.

Application (implementation of interventions)

It is necessary to uses the scientific methods of descriptive, analytic, experimental epidemiology as well as experiences, epidemiologic judgments, and understanding of local conditions in 'diagnosing' the health of a community and proposing appropriate, practical, affordable and acceptable public health interventions to control and prevent disease in the community. The inferences of epidemiological studies can be applied to a whole population or sub-group in defined geographical areas or a family or an individual depending of the situation, e.g. prevention of genetic diseases.

Warren Winkelstein (2000) described the need for a 'more **expansionist approach**' in order to address disease problems arising from pollution, global warming, population growth, poverty, social inequality, civil unrest, and violence. Even without taking the further step of proposing that epidemiology policies are implemented (country, state, district, villages, houses).

Graphical information systems (GIS) have really been around for as long as there have been maps (Fig. 1.2).

At the heart of the matter is the emphasis on 'where'? — 1. Where do disease's spread? 2. Where are the persons or communities most at risk? 3. Where are resources located that best supply their demand or potential demand? 4. And, of course, once we know 'where', we are in a much better position to ask 'why'.

GIS has a language all its own. The World Geodetic System (WGS84) is a graphical representation of the world, that transforms a 3D sphere to 2D map made of points, lines, polygons, (vectors), grids (raster), and their associated data attributes.

In general, you can represent topography with a series points (each with its own value), in a grid (a tessellated plane of pixel-like data, e.g. digital camera images and computer screens), or with contour lines (polygons).

Computing just makes them more comprehensive, accurate and available to non-cartographic folks. There are a number of open source and free tools available to epidemiologists to help incorporate GIS into their armamentarium. The two most important are GRASS 1 and R. There has also been some movement away from toolbox programs (like ArcGIS) to more service-oriented tools, like Google Earth (to which R and GRASS can also interface).

Need for Spatial Methods

All epidemiological studies are spatial! When do we need to 'worry', i.e. acknowledge the spatial component? "Are we explicitly interested in the spatial pattern of disease incidence?" For example, disease mapping, cluster detection. Is the clustering a nuisance quantity that we wish to acknowledge, but are not explicitly interested in? For example, spatial regression. If we are interested in the spatial pattern then, if the data are not a complete enumeration, we clearly need the data to be randomly collected in space.[12]

Elliott *et al.* identified four types of spatial analyses in epidemiology:

1. Disease mapping,
2. Geographical correlation studies,
3. Risk assessment in relation to point or line sources, and
4. Cluster detection and disease clustering.

Types of Data

An important distinction is whether the data arise as: Point data in which exact residential location exist for cases and non-cases, or count data in which aggregation (typically over-administrative units), has been carried out.

GIS can answer the following questions.

Condition: What is ……… ?
Location: Where ………….. ?
Trend: What is the change since…….?
Pattern: What spatial pattern……….. ?
Modelling: What if …………………?

GIS applications in public health/epidemiology:

- Simple visualization
- Mapping risk
- Location allocation
- Mapping disease spread
- Neighborhoods and health

Functions of GIS

1. Prepare thematic maps
2. Overlaying the pieces of information
3. Creation of buffer areas nearby selected points
4. To do specific calculations, e.g. proportions, distances, etc.
5. Create link between database and maps
6. Process aerial and satellite images
7. To provide extrapolation techniques

Fig. 1.2: Graphical information system

producing practically usable knowledge (evidence, findings, information, etc.) which can improve program implementation (e.g. effectiveness, efficiency, quality, access, scale up, sustainability) regardless of the type of research (design, methodology, approach) falls within the boundaries of operations research".

Supporting this practical definition are three basic steps to guide operational research:

1. Spell out well-defined goals and objectives of the health programme or system in question
2. Identify, prioritize and articulate constraints and obstacles that prevent these objectives being achieved
3. Develop research questions that address the constraints.

To successfully undertake relevant operational research, it is necessary to have a common understanding of what is meant by operational research as well as agreement on the key principles.

Operational research is different from clinical or epidemiological research in that it examines a system (healthcare system) rather than focusing on an individual or a group of individuals (as in clinical or epidemiological research where patients are examined).[14]

The usual epidemiologic approaches—descriptive, analytic, and experimental—are all used in health services research and, in addition, methods of evaluation have been expanded through their application to problems in health services.

Operation research is crucial with its useful modelling techniques, it helps to identify, quantify and solve problems related to healthcare system like resource allocation, congestion/queuing problems, risk analysis, assessment of healthcare projects, disease prevention, etc.[15]

Many studies pointed out the new ways of dealing with problems, services at the door step rather than in hospital, simple technologies at low cost, how to deal with health workforce issues, etc. through operational research (Table 2.5).

Triangulation operations research studies can integrate, harmonize and optimize the working of healthcare services at all levels. It can help in optimal use of health workforce, funds, infrastructure, supplies, and continuity of services with high efficiency and services security. Broad areas of operational research are mentioned in Table 2.6.

The community-based approach will have wider impact on health status of individuals, families and community as a whole.

INDIVIDUAL'S RISK AND CHANCES OF ILL-HEALTH[18,9]

WHO defined risk factor as "any attribute, characteristic or exposure of an individual that increases the likelihood of developing a disease or injury". Some examples of the more important risk factors are underweight, unsafe sex, high blood pressure, tobacco and alcohol consumption, and unsafe water, sanitation and hygiene.

To prevent disease and injury, it is necessary to identify and deal with their causes—the health risks that underlie them. Each risk has its own causes too, and many have their roots in a complex chain of events over time, consisting of socio-economic factors, environmental and community conditions, and individual behaviour. The causal chain offers many entry points for intervention.

Some risks located further back in the causal chain act indirectly through intermediary factors. These risks include physical inactivity, alcohol, smoking or fat intake. For the most distal risk factors, such as education and income, less causal certainty can be attributed to each risk. However, modifying these background causes is more likely to have amplifying effects, by influencing multiple proximal causes; such modifications therefore have the potential to yield fundamental and sustained improvements to health. In addition to multiple points of