Introduction to the Modelling of Venereal Disease

Norman T. J. Bailey
Health Statistical Methodology, World Health Organization, Geneva, Switzerland

Summary. The continually rising trend in the incidence of venereal diseases, especially gonorrhoea, in a large number of countries, both developed and developing is causing considerable public health concern. There is a disquieting volume of human suffering involved, as well as large economic losses in treatment and hospitalization. The present paper reviews the existing state of development in the mathematical modelling of the relevant disease dynamics. The ‘criss-cross’ nature of the infections, which in heterosexual contacts switch between the male and female populations, together with the nonlinear form of the rate of spread normally occurring in infectious diseases, leads to special types of simultaneous nonlinear differential equations.

The simplest deterministic models available entail threshold phenomena connecting the maintenance of endemic states to the contact-rates, the person-to-person infection-rates, and the removal-rates. A few stochastic results are also available.

Special attention is given to the aspects of nonhomogeneous mixing, analysis of contact-rates, infection without immunity, allowance for asymptomatic infection, the recognition of many different classes of infected individuals, and the problems of public health forecasting and control. In some cases transient solutions of the equations can be used to forecast future trends in disease incidence, depending on appropriate assumptions about alternative public health interventions.

It is concluded that further mathematical work should be concentrated on relatively simple models comprising no more than three or four district epidemiological groups for each sex. There should be both (i) more intense mathematical investigations, and (ii) new attempts to assimilate the models directly to public health venereal disease control.

Key words: Mathematical modelling — Venereal disease — Gonorrhoea — Criss-cross infection — Nonhomogeneous mixing — Asymptomatic infections — Public health control.
1. Introduction

The widespread occurrence and increasing incidence of venereal disease, or sexually transmitted disease, is today a major public health problem in developed and developing countries alike. Thus in the USA in 1973 approximately 767,000 cases of gonococcal infections and 91,000 cases of syphilis were notified. All other infectious diseases notified, including chickenpox, mumps, hepatitis, tuberculosis, measles, rubella etc., totalled only 454,000. Because of under-reporting, as deduced from relevant surveys, the overall incidence of gonorrhoea was believed to be in excess of 2.5 million out of a total population of 250 million, the cases being divided in the ratio of 3:2 between males and females.

Again, in a survey covering several Asian countries it was found that between 20 and 55% of university students had contracted a gonococcal infection within a one-year period. In family planning centres in countries of Central Africa, some 17% of women were found to have the same infection.

Such figures give some indication of the world-wide scale of the problem. The total world incidence of sexually transmitted diseases, especially syphilis, gonorrhoea and non-gonococcal urethritis, is probably surpassed only by such diseases as malaria, schistosomiasis, filariasis, hookworm disease and trachoma, each of which involves hundreds of millions of people.

The main public health problems arise from the morbidity occurring in untreated infected persons. These can be anything from minor irritations to serious clinical symptoms in a variety of other organs. Even where health services are quite well developed it is common for some 10 to 20% of women with gonococcal infections to suffer from severe pelvic complications. Indeed as many as 90% of women admitted to hospital for a first attack of acute pelvic inflammation have been found to be infected with the causative agent of gonorrhoea.

Apart from the health risks to individuals, the cost to the community in treatment can be very considerable. The economic cost of handling the complications of gonorrhoea in women was estimated (based on a study in Memphis, Tennessee) for the whole of the USA in 1972 to be of the order of $212 million. Hospital admissions for women with complications due to gonorrhoea are reckoned to total over a million bed-days annually. The treatment of syphilis was estimated in 1973 to cost the US taxpayer some $49 million per year for the hospital maintenance of a total of 91,000 cases in all stages of the disease. These figures do not include the cost of private medical care for 85,000 new cases occurring in 1973. There were, moreover, believed to be around 500,000 untreated cases of all stages of syphilis! An analysis made in 1968 estimated the economic benefits to be obtained from a control program to eradicate syphilis as possibly amounting to a saving of more than $3,100 million.

The above estimates (see World Health, May 1975) provide some idea of the magnitude of the world health problems involved. Naturally, the figures are given for countries where good records exist or special surveys have been carried out. But there is reason to believe that the serious situation revealed is universal, affecting communities in all stages of development.