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Technology, Development

Modern concepts of epidemic theoryoriginated from the work of William Farr, the first epidemiologist to begindiscerning mathematical principles governing the behaviour of infectiousdiseases. The basic reproduction number of such an infection, R0, isdefined as ‘ the number of cases that would result directly from theintroduction of a single infectious individual into a susceptible population’ andis therefore effectively synonymous with ‘ transmissibility’: R0 = C xP x D In which C represents the average rate ofcontacts made between an infected individual and susceptible individuals in thepopulation, P is the probability of transmission from each contact and D is theduration of infectiousness. An R0 value of 1 thereforeimplies that a single infectious case will cause, on average, one other, whereasan R0 of less than 1 indicates the disease will eventually disappear, and an R0 greater than 1 indicates continual spread of infection. Hence, in order to eradicate an infection, we must attempt to alter the host pathogenrelationship in such a way that R is decreased below 1.

It is unlikely in any actual populationthat every single individual will be susceptible to a particular disease, theeffective reproductive rate, R, therefore estimates the average number ofsecondary cases in a given population consisting of both susceptible andnon-susceptible individuals. R = R0xIn which X represents the fraction of thepopulation which is susceptible to the disease. X will be reduced inpopulations which have previously encountered a disease, and hence a greaterproportion of individuals have acquired immunity. This is also seen in publichealth measures which promote immunization; “ When an individual is successfully immunised, not only is thereone less person who will ever be infected, there is also one less person whowill be infectious” (McLean, 1992). Vaccination therefore acts to decrease theinfectious pool in such a way that it provides protection even to those whohave not received the vaccine, known as herd immunity. In order to completelyeradicate a disease, the critical level of vaccination (also known as the thresholdfor herd immunity) can be calculated from R0, giving the extent towhich the pool of succeptible individuals must be reduced; Pc = 1-1/R0 The larger R0, and hence the greater the transmissibility of a condition, the larger Pcmust be in order to eradicate the disease.

MeaslesMeasles has a high R0 andtherefore a very high proportion of the population must be vaccinated in orderto eradicate the disease. The viral disease causes serious complications, including encephalitis and pneumonia as well as suppressing the immune system, increasing the P value for other epidemics. As a result, measles remains a major causes ofdeath, however, the introduction of a successful vaccine is believed to have decreasedchild deaths by 1/5th since 1990. The importance in this vaccinationprogram can be seen in the aftermath of the publication of Wakefield’s work ina 1998 Lancet paper.

This paper implicated the MMR vaccine in the developmentof autism in young children, which, despite the paper stating that no causalrelationship had been proven, and further studies finding no relationship atall, resulted in a huge decline in confidence in the vaccine, and hence a rise inthe number of parents refusing it for their children. This has been implicatedas the major cause of the rise seen in measles cases following the paperspublication, In 2008 for example, measles was declared endemic for the firsttime in 14 years. This illustrates the dramatic effect that may be caused by aseemingly small decline in vaccination rate – it is thought that a 5% fall inMMR vaccine administration may result in a threefold increase in measles cases. The 2008 endemic was particularly prevalent in festivals, thought to be aresult of the increased rate of contact, increasing R0; R0 = ?/? In which B is the no. of contacts per unittime which will result in new infections and 1/y the mean infectious period. SmallpoxSmall pox is also a virus which, incontrast to measles, has a reasonably low R0 and has therefore been oneof the only 2 diseases to be officially declared eradicated (alongside rinderpestin 2011), despite over 15million cases occurring each year as recently as 1967. Small pox is highly contagious, with a high P value, however the duration ofthe infectious phase is short and occurs only following onset of the rash, andwith reasonably close contact (within 1.

8m), and hence R0 is lowerthan measles and many other viral diseases. The eradication of small pox hasbeen made far easier by the lack of alternative hosts which may provide areservoir for the disease (for example mosquitos in malaria) and has reliedprimarily on widespread vaccination programs and careful surveillance andisolation of outbreaks. HIVOne of the most effective methods of reducingthe incidence of AIDS, for which there is no vaccine, is to reduce the risk oftransmission, P, by the use of anti-retroviral therapy. By 2020 the jointUnited Nations program on HIV and AIDS has set a target to ensure 90% of allpeople infected with HIV are aware of their status, 90% of them are onanti-retroviral therapy and 90% of those on therapy will have full viral loadsuppression.

This will result in 73% of those who have HIV achieving full viralload suppression, which, if maintained should enable elimination of HIV in 70%of Sub-Saharan countries and reduce R0 to less than 2 in the remaining 12countries, compared to the current median R0 of 4. 3. in combination with otherhigh-impact preventative methods such as promotion of condom use and an increasein the availability of Pre-exposure prophylaxis (PrEP) could potentially seethe eradication of AIDS. PrEP enables a reduction in the number of susceptibleindividuals who may come in contact with those which are infectious, and hencea reduction in C similarly to vaccination.

If taken consistently it has beenshown to reduce the risk of infection by up to 92% in high risk individuals. Without treatment, the risk of transmission ofHIV from sexual intercourse is considered to be approximately between 0. 001 and0. 1 but the use of condoms has been found to reduce this by 80 – 85%. One studyfound that in 123 discordant couples who consistently used condoms none of theuninfected partners became infected, in comparison to 12 uninfected partnerswho contracted the disease out of 122 couples using condoms inconsistently.   IMMUNITYand mutation? FLU ChildhooddiseasesR0 can in fact be estimated from theaverage age of infection.

This is because there is a greater chance ofencountering a disease with a high R0 (i. e. a high transmission risk and manyinfectious people) earlier in life. Such infections are commonly termed ‘ childhooddiseases’ since the majority of people are infected at a young age, conferring acquiredimmunity for the remainder of their lives. By this estimation: R0 = 1 + L/A In which L is the average lifespan and Athe average age at infection. Chicken pox is one such disease in whichearly infection is common since the infectious period begins 1-2 days prior toa rash appearing, unlike small pox, preventing cases from being identified andisolated.

This is coupled with a high probability of transmission – studies oftransmission have found that over 90% of close, susceptible people in contactwith a diseased individual will be infected, resulting of an R0value of approximately 11. Generally, contraction of the disease results inimmunity to future infection (although latent infection may be reactivated) sooutbreaks are rarely seen in adult populations. Pertussis, by comparison, has amuch lower R0, of approximately 5. 5 and as a result is more commonlyseen in older populations, as supposed to just the very young. Since the R0value of chicken pox is so high, but the symptoms of the disease, particularly inchildren, are relatively mild in comparison to pertussis, it is not commonly vaccinatedagainst in the UK. Limitationsof R0: R0 is always an average value –as not all infected individuals will transmit the disease to exactly the samenumber of people, therefore if there is great variation in the rate of spreadamong different subgroups if the population, the average R0 will belargely meaningless. R0 is therefore most useful in explaining the dynamics ofa disease which is spread broadly among individuals who meet at random. R0 is difficult to observe andcalculate in the field and hence mathematical models are frequently used toestimated its value, however, the true value of R0 is rarelyactually derived from many mathematical models, which instead give a thresholdas supposed to the number of secondary infections.

This does have some benefitin determining the viability of an epidemic (with R0 >/< 1) however is ofrelatively little use in comparing the dynamics of two different diseaseepidemics.