ENGINEERING, MATHEMATICS, PHYSICS

HIV AND AIDS

A GENERIC INTEGRATION COURSE
MODULE FOR UNIVERSITIES
IN SUB-SAHARAN AFRICA

Revised Edition

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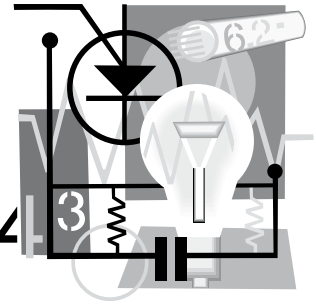


PREAMBLE

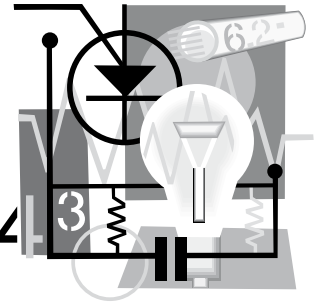
Given the dire situation of HIV and AIDS pandemic in the resource strained countries (sub-Saharan Africa), and the fact that students generally fall into a high-risk group, within the context of UNESCO's prevention Education Programme and the Organization's contribution to the achievement of the Millennium Development Goals, a series of training of trainers workshops were jointly organized by UNESCO's Regional Bureau for Science and Technology in Africa and the African Women in Science and Engineering (AWSE) for Universities in Ghana, Rwanda, Botswana and Kenya during the 2006/2007 Biennium.

The training workshops for Science and Engineering lecturers had been preceded by a regional workshop for Deans of Faculties of Science and Engineering within the context of "Higher Education Science and Curriculum Reform: African Universities Responding to HIV and AIDS". The main purpose of the regional workshop was to share information and learn from the experiences of different African universities on how they were addressing the impact of HIV and AIDS in their institutions, and to come up with strategies for effective mainstreaming and integration of HIV and AIDS into their courses. On the other hand, the workshops were meant to provide training for lecturers from Universities on how to mainstream and integrate HIV and AIDS into the Engineering and Science Courses within their respective universities, and also prepare them as trainers of trainers within their respective faculties and the institution as a whole.

This generic integrated module is an output of the UNESCO/AWSE in-country Training Workshops on Mainstreaming and integration of HIV and AIDS for Physical and Engineering Sciences in Ghana, Rwanda, Botswana and Kenya. It summarizes the various country integration modules in mathematics, physics and engineering and the potential entry points for integrating HIV and AIDS materials.

This is a consolidated result of input of participants from the 6 Universities in Ghana, 3 public Universities in Rwanda, 2 Universities in Botswana and 17 Universities in Kenya, and is based on their curricula in the teaching of mathematics, physics and engineering. This report develops three generic module templates, each from mathematics, physic and engineering, respectively. These three modules are very generic in nature, and can be immediately adopted by all participating universities and other higher education institutions.

Country specific modules have been developed separately to suit each country's respective university course outlines. These sample modules have been developed from the existing modules in selected areas of Mathematics, Physics and Engineering. The content of the current teaching units remains the same but there is HIV and AIDS education and HIV related examples. Each teaching unit should be covered in exactly the same time frame as before. The focus of the unit also remains the same. It is anticipated that the student will not only learn the basic materials in mathematics, physics and engineering as prescribed in the course, but will also be introduced to some HIV and AIDS knowledge that could influence the perception, behavioral change, and demystification of the disease, thereby contributing to the fight against HIV and AIDS in the universities and the communities at large. This could be considered as an additional expected outcome of the courses. The intergrated courses are also expected to raise the intrests of the students in pursuing further research on HIV and AIDS within the framework of their respective professions.



ACKNOWLEDGMENT

This generic integration module has benefited from the inputs of participants at the UNESCO/AWSE in-country Training Workshops for Universities in Ghana (6-8 December, 2006; 24-30 March, 2008), Rwanda (28 - 30 March 2007), Botswana (17 - 19 April 2007) and Kenya (08 - 10 May 2007), on Mainstreaming of HIV and AIDS in the faculties of Science and Engineering and integration into the Physical, Biological and Engineering Science courses.

The training workshops were facilitated by Prof. Xiaohua Xia from the University of Pretoria, Department of Electrical, Electronic and Computer Engineering and Dr. Mandu Jeffrey from the University of Botswana, Department of Electrical Engineering.

Profound gratitude and further acknowledgement is expressed to UNAIDS who made the production of these modules a reality through their Unified Budget Work plan (UBW) funds.

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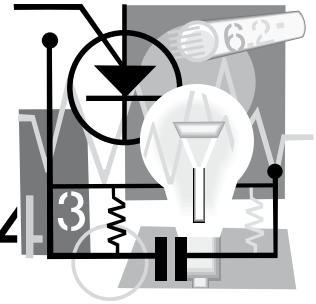


MATHEMATICS

Analysis/Calculus

Mathematical analysis or calculus is an excellent choice in integrating HIV materials into the teaching. Mathematical analysis is taken by the first year mathematics students, and calculus is taken by all first year engineering students. The expected outcome of this integration is to impart the students with basic HIV response while teaching elementary mathematics concepts.

Course description

The module investigates concepts of single variable functions, limits, continuity, graphs and differential calculus. Also the module deals with concepts of foundations of analysis (sets; logic; proofs, real number system and relations) which have hitherto been approached very intuitively and investigates basic mathematical ideas of definition and proof at an appropriate level of formalism and rigor.

Entry points

1. Basic Concepts

Objective: Rigorous review of limits, derivatives/differentiation, integration, the elementary single variable function: exponential function.

Integration with HIV

a) Limits, continuity and differentiability; tell the students that a continuous function is similar to a person who is HIV negative, and because of this, they continue living without so many conditions, unlike the HIV positive who must be on diets to live long just like the functions which will be undefined if some conditions are not heeded.

b) Partial differentiation; one may have one of the variables being considered as the HIV. By this consideration, it is possible to explain to the students how this virus differentiates the whites cells selectively with respect to time amidst other cells, thereby reducing the immune

levels of the person affected.

c) Integration; in the review of the techniques of integration, it is easy to demonstrate how complicated functions can be broken in partial functions (partial fractions) and integrated separately and later summed to find an ultimate solution. In the same way, we may divide an rule/administer to people with HIV and AIDS. In reduction formulae, we get a structure that can be used to integrate any other function that takes the shape of a known one. In the same way we may develop a therapy to be used by all the patients in possession of particular characteristic or at a given stage/phase of the disease. In the same topic of integration, we demonstrate how integration is a limit of a sum. This can straight away be related to the fact that AIDS is the limit of HIV.

d) Growth and decay; the very introductory concepts of growth curves may capture the manner in which HIV and AIDS prevalence is increasing or decreasing in a certain village. This may simply be mentioned as a highlight or some data may be provided for the students to fit into the growth curves.

e) Differentiation and application of derivatives
   1. Viral load against time
   2. CD4 count against time

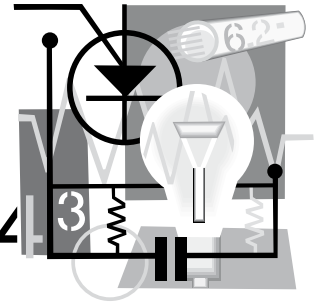
f) The short-term (< 4 weeks) viral load response after anti-retroviral therapy can be approximately represented by an exponential decay function of time. The rate of decay is related to the half-life of infected CD4+ T cells;

g) The viral load rebound (viral load blips) after termination of therapy can be approximately represented by an exponential growth function of time. The rate of growth is usually greater than the decay rate as in f).

h) Differential calculus (Example of predator- prey model and its uses in HIV and AIDS modelling)

2. Graphical and Analytical solutions

Plot the viral load response and rebound after initiation of therapy and termination of therapy respectively.



PHYSICS

P101: Mechanics I/Physics

This is a first year course for all physics departments. It is also offered in the form of a service course to students from other departments. It presents an excellent point of entry for integrating HIV into a hardcore science course. The expected outcome of the integration is to impart knowledge to the student in their first year of study on how HIV infection takes place and how it progresses while teaching basic scientific techniques of measurements.

Course description

Measurement of physical quantities, dimensional analysis, kinematics. Introduction to inertial and non-inertial frames of reference, dynamics of a particle.

Conservation laws: Conservative forces, potential energy, the centre of mass of a system of particles and its motion, centre of gravity, conservation of energy of a system of particles, conservation of linear momentum: collision of two particles in one and two dimensions (elastic and inelastic), motion of a rocket; conservation of angular momentum. Dynamics of a rigid body: Equilibrium of a rigid body, angular momentum of a rigid body and moment of inertia, equation of motion of a rotating body, kinetic energy of rotation, gyroscope, precisional motion of a spinning top. Motion under central forces: Simple harmonic motion, circular motion of particles and bodies, planetary motion and gravity, elliptical and other orbits, Rutherford scattering: scattering of a charged particle by a nucleus.

Entry points

1. Size and Measurement of HIV

- The size of an HI virus – demonstrates that condoms are not really safe. Condoms are by nature porous materials and the size of the virus is much smaller than the holes on the condom.

- Units of measurement.

- Measurement: precision and accuracy related to the accuracy of HIV measurement (tests).

- Relationship to false-positive and false-negative test results.

- Temperature – instruments – ways to reduce risks of transmission (Avoiding risks of transmission e.g. measuring body temperature of HIV and AIDS patients – digital electronic thermometers in comparison to use of conversional clinical liquid in glass thermometer – waste avoid risks of transmission through body fluids - sweat, under tongue).
  Body mass
  CD4 count - instrument used
  Viral load – instrument used.

- Data Analysis (tabulating and graphing normal scale or log scale). CD4 count, viral load, temperature graph, body mass graph.

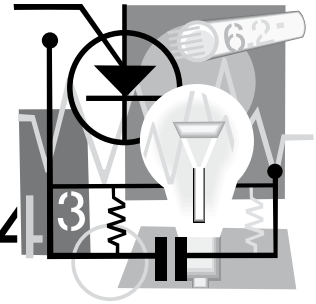
- Calculation of average, variance, correlation and linear regression.
  - Calculation of average of people who are HIV and AIDS positive
  - Estimate the number of people who will be affected by HIV and AIDS once they don't take precautions.

- Show mathematically the distribution of HIV and AIDS in space and in time.

- Standard deviation in a number of measurements; Precision improved with multiple measurements, or measurements made by more than one person, measurements with more than one test.

- Investigate relationship between length of time of administering ARV drugs and viral load.

a) Collection of viral load data, in normal scale and log scale
b) Plot the viral load data in log scale
c) Discussion of measurement precision and measurement error



2. Stability/instability of HIV and AIDS equilibrium

- System of particles: Cells in the body as a system. Virus (energy) entering the cell, replicating (work) and budding out of the cell.

- Conservation of energy: If energy is being used to fight off disease there is not much left to do useful work.

- Reversible and irreversible processes compared to the irreversible nature of HIV

- Thermal equilibrium (or 0th law): If three systems (in this case people) are "interacting" they will come to equilibrium, i.e., if one is infected they will all be infected.

- Thermal equilibrium: Taking drugs can bring a state of equilibrium where the rate of reproduction of the virus is equal to the rate of elimination.

- Thermal diffusion: The HIV virus spreads quickly throughout the entire body and is not contained in a local area where it might be treated more easily.

a) Instability of uninfected status
b) Stability of infected status

3. Sedimentation velocity of red globules in plasma

ENGINEERING

ICB Safety and First Aid

This course has been identified as an ideal course to include HIV knowledge. It is usually offered as a service course in the first year right before any practical session takes place. In an advanced format, it is also offered to senior students in engineering. The following is an expansion of the existing module. The bold fonts are added parts.

Course Description

Aims and Learning Objectives:

The course aims at providing specific and in-depth knowledge of workshop safety and first aid. On successful completion of all activities, a student will be able to:

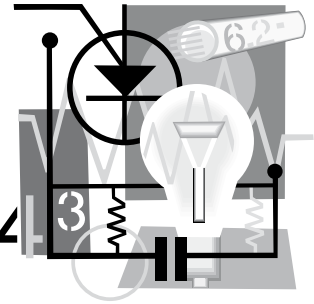
- Identify and apply general safety rules
- **Identify HIV and AIDS risks**
- Manage safety in the work place
- **Manage HIV related problems**
- Work safely with a range of materials, tools and machines
- Describe the treatment of cuts, burns, bruises and electric shocks
- Treat cuts, burns, bruises and electric shocks with **due regard to HIV risks.**

Rationale

Every workplace has safety standards that all workers must learn to employ materials, tools and machines. **Safety must be observed everywhere.** This course prepares a student **to understand the HIV related risks** and to provide first aid when required **with due regard to HIV prevention.**

Course Synopsis:

Safety rules, Causes of accident in the workshop, Methods of identifying types of injuries and methods of administering first aid. **HIV and AIDS scenario and Precautions.**



Course Outline:

Safety rules, **HIV Risks,** Youth Susceptibility, Safety practices, Safety symbols and their interpretations, Causes of accident in the workplace, Types of accident/injuries in the work place. Methods of giving First Aid to different cases of accident/injuries: Burns, wounds, Fractures, Poisoning and Shock. First Aid kit at the workplace. **HIV and AIDS Prevention.** First Aid and personal safety. Preventative measures of handling contagious and infectious diseases **including HIV. Accident and Trauma Care Training.**

Mode of Assessment

Two assignments and two practical tests and the First Aid and Accident Care test at the end of the course.

Entry points:

1. Case study: HIV and AIDS related topics

- AIDS prevalence in the university, community, etc.
- Behavioural studies.

2. Health, Safety and Welfare

Industrial safety

- Emphasise the importance of prevention – prevention of accidents in the workshop/workplace and of contacting HIV infection.
- Wearing protective clothing at work like helmets and gloves is similar to wearing condoms.
- The ABCs of HIV infection prevention have been stated as follows: Abstain, Be faithful, Condomize.
- Injuries should be handled with care to avoid contact with the injured person's blood or other body fluids.
- Identify the location and contents of the first-aid box in the laboratory.

Personal safety and hygiene

- Ones body should be kept safe, clean and healthy.
- Poor health and safety practices lead to HIV infections, the same way poor harvest storage facilities lead to infestations by bacteria,

weevils and the likes.
- Again, the same way the weevil goes for the corn kernel is the same way the HI virus goes for the body's immune system cell – both lead to spoilage and impaired functionality.

3. Impact of HIV and AIDS
- HIV and AIDS denial and reality
- HIV and AIDS impact on the individuals learning process
- Downtime due to HIV and AIDS
- Environmental impact assessment; impacts of HIV and AIDS on the environment.
- Effects of condoms on the environment.

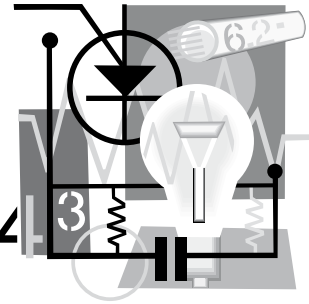
4. HIV and AIDS Transmission
- Methods of HIV and AIDS transmission
- Conditions that aid HIV and AIDS transmission
- Ask the students how HIV infection can be transmitted in a workshop or laboratory.

5. Sanitation and HIV infection
- Transmission of disease from excreta and control; Explain methods of human excreta disposal.
- Sanitary conditions for HIV and AIDS positive people.

a) Engineering ethics relation to HIV and AIDS infected and affected.
b) What can I as an individual do to contribute to an AIDS free community?

Reading (and other resources) list:

1. Safety Handbook for Science Teachers. By K. Everett and E. W. Jenkins (1977) ISBN 0-7195-3336-8
2. The South Africa First Aid manual: Emergency procedures. St John Ambulances (2000).
3. AIDS Education Booklet, UB or Alternative Text appropriate to the topics
4. Identified Videos on Safety and HIV and AIDS Prevention.



Appendix: Scientific Background Materials on the Dynamics of HIV

A.1 Virus Replication

When the HI virus enters the body, it directly seeks out the immune system cells because the virus can recognize the CD4 receptor on the surfaces of these cells. Upon making contact with such a recognizable cell, the virus attaches to the CD4 receptor. However, the virus needs to attach to a second co-receptor for it to pull itself across the cell membrane. This secondary co-receptor could be CXCR4 or CCR5. After the virus attaches to the co-receptor, the host cell and virus membranes then fuse, the virus enters the cell and proceeds to replicate within the cell as illustrated in the following figure *(http://www.aids.org/factSheets/)*.

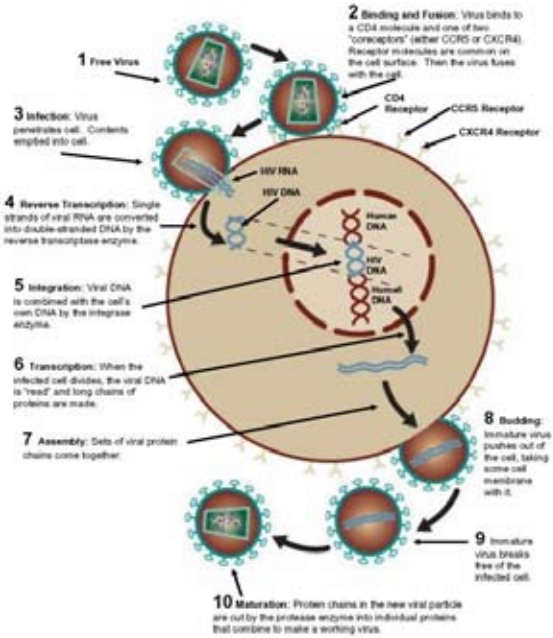


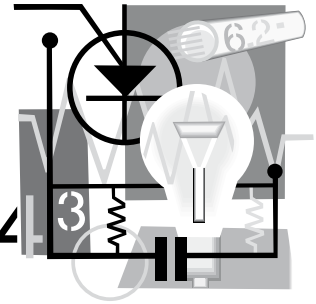
Figure 1

Eventually, multiple copies of the virus are released, and in the process, the immune cells are destroyed in large numbers, and certain cell pools are even depleted. This leaves the body with little or no defense against disease causing invaders.

The main replication stages identified here are:

- Attachment and binding. Entry inhibitors disrupt either one of these processes.
- Fusion of membranes and infection.
- Reverse transcription. Reverse transcriptase inhibitors disrupt this stage.
- Integration.
- Transcription.
- Assembly. Protease inhibitors disrupt this stage.
- Budding and maturation.

Technically, if any of the virus replication stages identified above can be disrupted or blocked, then inhibition of virus replication would occur. This is the underlying rationale behind antiretroviral drugs, as ARVs are designed to disrupt a particular stage of the virus replication cycle. However, the replication process is error prone, and consequently, some of the virus particles released are mutants that can also replicate. This gives rise to resistance to antiretroviral drugs.



A.2 Virus – CD4+ T Cell Dynamics

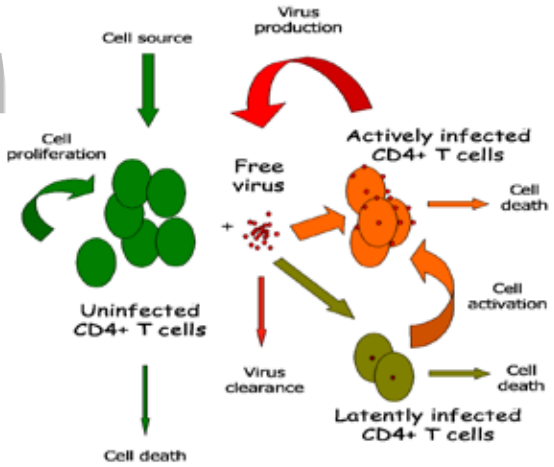


Figure 2

The above figure is a schematic illustration of the interaction between the HI virus and the immune system CD4+ T cells. The interaction can be broken down as follows:

- Uninfected CD4+ T cell production from the thymus and the natural cell death.
- Cell infection by the virus – Infected cells can be latent or actively produce virus.
- CD4+ T cell proliferation in response to infection/antigen.
- Activation of latent cells and latent cell death.
- Virus production by active cells and accelerated CD4+ T cell death due to infection and virus budding.
- Virus clearance from circulation.

This virus – target cell schematic illustration can be represented mathematically by a set of first order differential equations as follows:

$$\frac{dT}{dt} = s + pT\left(1 - \frac{T + T_l + T_a}{T_m}\right) - dT - \hat{a}TV$$

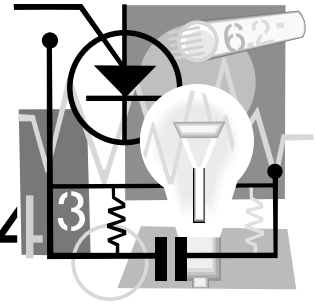
$$\frac{dT_l}{dt} = q_l\hat{a}TV - kT_l - \ddot{a}_l T_l$$

$$\frac{dT_a}{dt} = q_a\hat{a}TV + kT_l - \ddot{a}_a T_a$$

$$\frac{dV}{dt} = rT_a - cV$$

s	–	source rate: Uninfected T cell
p	–	proliferation rate: Uninfected T cell
Tm	–	proliferation shut down T cell count
d	–	death rate: Uninfected T cell
b	–	infectivity rate: T cell by virus
ql	–	probability: Latent T cell
qa	–	probability: Active T cell
dl	–	death rate: Latent T cell
da	–	death rate: Active T cell
k	–	activation rate: Latent Æ Active
r	–	production rate: Virus
c	–	clearance rate: Virus
**		All parameters are rate constants except for s

The meaning of each variable and parameter follows directly from the schematic. These equations can be used to simulate the HIV infection dynamics. The equations need to be linearized for analysis by undergraduate students.



A.3 The Immune Response to Infection

The immune system is made up of different types of white blood cells (lymphocytes), antibodies and some active chemicals, whose responsibility it is to defend the body against any disease causing foreign invaders.

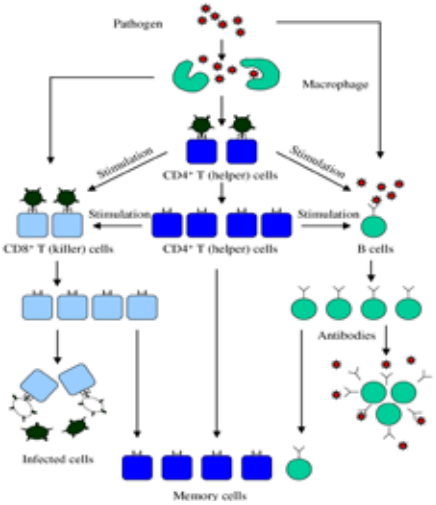
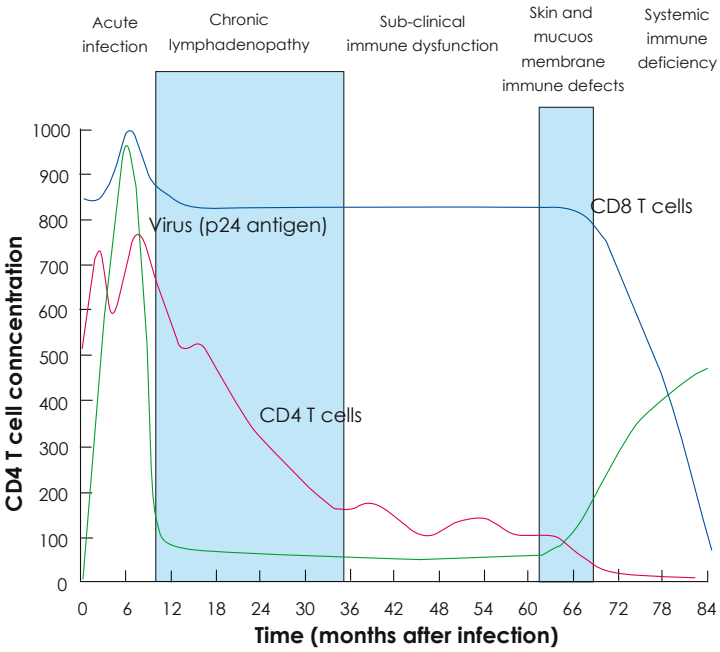


Figure 3 (Kirschner, 1999),

The immune cells, as illustrated in the figure above, work together to defend the body by identifying, disabling and destroying the invader. White blood cells can be categorized as B cells (B lymphocytes) or T cells (T lymphocytes). B cells are derived from the bone marrow and spleen, whereas T cells are derived from the thymus gland.

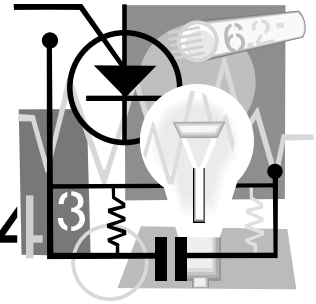
A.4 Typical Course of HIV Infection

Fiaure 4



The above figure shows a typical course of HIV infection. The course has 3 main stages, namely the acute or primary infection stage; the asymptomatic or clinical latency or chronic infection stage; and lastly the advanced or AIDS stage.

- ACUTE HIV INFECTION: This is the period of rapid viral replication immediately following exposure to HIV. An estimated 80 to 90 percent of individuals with primary HIV infection develop an acute syndrome characterized by flu-like symptoms of fever, malaise, lymphadenopathy, pharyngitis, headache, myalgia and sometimes rash. Following primary infection, seroconversion occurs. When people develop antibodies to HIV, they seroconvert from antibody-negative to antibody-positive. It may take as little as 1 week to several months or more after infection with HIV for antibodies to the virus to develop. After antibodies to HIV appear in the blood, a person should test positive



on antibody tests. It was previously thought that HIV was relatively dormant during this phase. However, it is now known that during the time of primary infection, high levels of plasma HIV RNA can be documented.

- ASYMPTOMATIC: Asymptomatic means "without symptoms" and this period in HIV infection is also known as the clinical latency period. During this period in time, a person with HIV infection does not exhibit any evidence of disease or any clinically noticeable ill effects, even though HIV is continuously infecting new cells and actively replicating. The virus is also, during this period, active within lymphoid organs where large amounts of virus become trapped in the follicular dendritic cell network. The period of clinical latency varies drastically in length from one individual to another. There are reports of this latency period lasting only 2 years, while others report it lasting for more than 15 years. But normally, the duration in untreated individuals ranges from 7 to 10 years.

- ADVANCED – AIDS: After a normally long asymptomatic period, the virus eventually gets out of control and the remaining immune cells are destroyed. When the CD4+ T cell count has dropped lower than 200 per microL of plasma, the individual is said to have AIDS, and will succumb to opportunistic infections, because of the loss of immune competence.

A.5 Antiretroviral (ARV) Therapy

There are many antiretroviral agents that have been approved for the management of HIV. These agents can be categorized as replication cycle based or immune based. Replication cycle based drugs that are currently used are the entry inhibitors – EI, reverse transcriptase inhibitors – RTI and protease inhibitors - PI, so named depending on the stage of the replication cycle that the particular drug disrupts. Immune based drugs such as Interleukin-2 modulate the immune system.

Highly active antiretroviral therapy – HAART entails the concomitant use of multiple drugs from different classes of inhibitors.

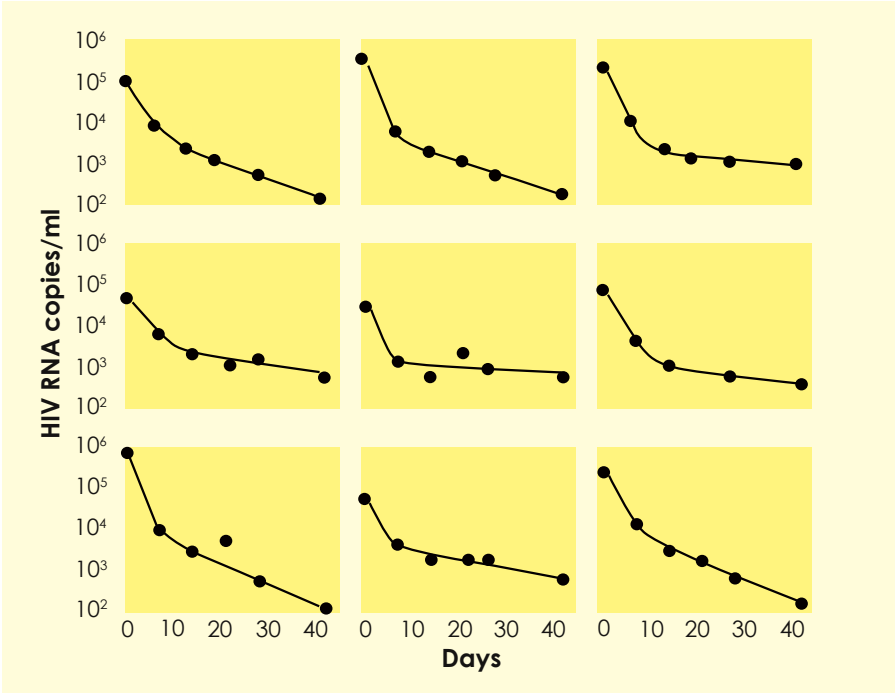
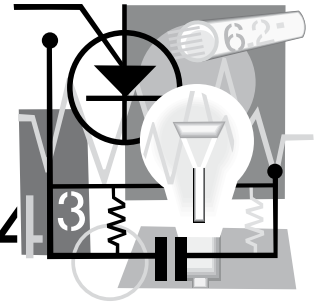


Figure 5

The above figure shows the HIV RNA response of nine typical patients after the initiation of therapy as day zero. Viral load suppression is considered to be maximal when the viral load reaches below levels of detection by the currently available assays. Given the initial viral load and CD4+ T cell count, the minimum viral load and duration of viral load suppression to below 50 copies per mL of plasma, if attainable, can be determined mathematically because the response follows approximately an exponential decay function. This minimum value below 50 copies per mL that the viral load can be reduced to is currently not clinically quantifiable as it can not be readily measured.

However, an estimate of the minimum value that the viral load can be reduced to is useful in determining whether viral load suppression to below detectable levels can be attained, for a given drug dosage and instance when therapy is initiated.



Very early initiation of therapy can be expected to result in a shorter viral load suppression period and a rapid transition to the treatment steady state. Late therapy during the asymptomatic stage will most likely result in a prolonged viral load suppression period. Increasing the drug dosage would result in a longer period of viral load suppression. Given the foregoing, maximal suppression of the viral load will most likely be attained when therapy is initiated during the asymptomatic, very early and late acute infection stages of the infection, or when high drug doses are used. It is therefore possible for a drug dosage to be suppressive at one stage of the infection, but fail when therapy is initiated at a different stage. For a given instance when therapy is initiated, then the degree and duration of viral load suppression is drug efficacy dependent.

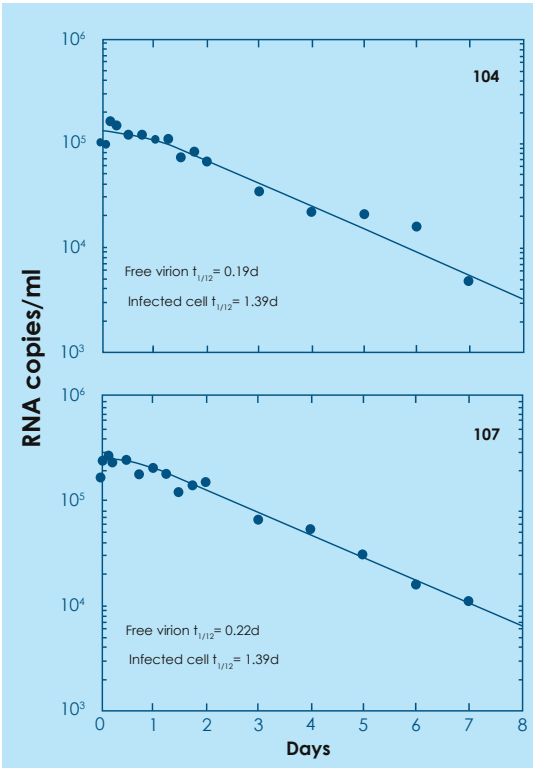


Figure 6

The above figure is a log scale plot of the RNA short term response of two typical patients after the initiation of therapy at day zero. The benefit of plotting the response in log scale is the straight line which his useful in estimating the half lives of the virus and infected cells.

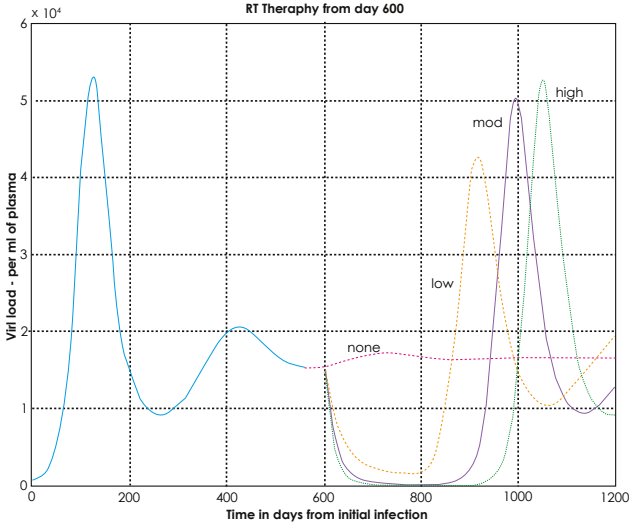
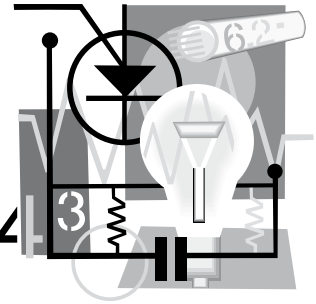


Figure 7

A set point or a steady state corresponds to the asymptomatic stage of an HIV patient. A typical control action (treatment) during this stage is to bring down the virus to a lower level. A successful antiretroviral therapy is designed to reduce the viral load by 90% in eight weeks and continue to suppress it to below 50 copies per mL of plasma in less than six months. Therapy is usually initiated during the asymptomatic stage. The set point of virus is also referred to as the baseline. The above figure demonstrates HIV infection at day zero and set point is reached at around 500 days from initial infection. If no therapy is started, the asymptomatic stage is maintained, but during this period the immune system is gradually damaged. An initiation of therapy is done around 600 days with a moderate dosage of drugs or with a high dosage of drugs. A moderate dosage might not be effective to reduce the viral load, while a high dosage could bring the viral load to undetectable levels. The figure also shows the viral load rebound after termination of therapies at around 800 days. Different sections of the viral response exhibit exponential growth or decays.



NOTES

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