



C M S A

The Colleges of Medicine of South Africa NPC

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JOHANNESBURG OFFICE
EXAMINATIONS & CREDENTIALS

January 2020

THE COLLEGE OF PATHOLOGISTS OF SOUTH AFRICA

R E G U L A T I O N S

FOR ADMISSION TO THE FELLOWSHIP OF

PATHOLOGISTS OF SOUTH AFRICA IN CHEMICAL PATHOLOGY

FC Path(SA) Chem

1.0 COMPONENTS

The examination comprises Part I and Part II: Part II must be passed within six years of passing the Part I

2.0 PURPOSE OF ASSESSMENT

The aim of this assessment is to evaluate if the candidate who has completed the minimum training period, has acquired the appropriate professional knowledge, skills and attitude stipulated by the HPCSA training requirements and standards in order to be licensed by the HPCSA as a practitioner of Chemical Pathology at specialist level. This assessment is one of two parts of the HPCSA requirement for registration as a specialist Chemical Pathologist. The other part of the registration requirement is assessment of a research report by the host University.

3.0 ADMISSION TO THE EXAMINATION

3.1 PART I (Basic sciences):

A candidate may be admitted to Part I of the examination having:

- 3.1.1 Obtained a post-community service/internship qualification to practice medicine which is registered with the Health Professions Council of South Africa (HPCSA)
- 3.1.2 Completed twelve (12) months fulltime post-community service/internship training as a registrar in an accredited teaching hospital department of Chemical Pathology at the time of applying to enter for the Part I. The part I examination will be implemented from January 2017. The training requirement will apply to all registrars commencing training from January 2016. Deviation from this requirement may be considered under special circumstances.

3.2 PART II

A candidate may be admitted to Part II of the examination having

- 3.2.1 Obtained a post-community service/internship qualification to practice medicine which is registered with the Health Professions Council of South Africa (HPCSA)
- 3.2.2 Completed Part I of the FC Path(SA) Chem examination. Exemptions to Part I may be considered on the basis of having completed a Part I equivalent examination acceptable to the College of Pathologists. This will apply from January 2017.
- 3.2.3 Completed three and a half (3½) years (42 months) of fulltime post-community service/internship training as a Chemical Pathology Registrar in an accredited teaching and training hospital/institution at the time of the application for the written examination.
- 3.2.5 From the second semester 2014 the submission of your Portfolio at the time of making your application is compulsory for all candidates who entered into their Registrar post from 1 Jan 2011.

4.0 SYLLABUS

The theory, principles and practice of physiological chemistry, abnormal body chemistry and the different biochemical procedures used in the investigation of disease. The details of the syllabus appear elsewhere in the document.

5.0 FORMAT OF THE EXAMINATION**5.1 The part I examination, with pass mark of 50% will comprise**

5.1.1 Two 3-hour closed –book written examination papers with a subminimum of 50%.

- Paper 1 will contain MCQs and short answer questions. The subminimum is 50%
- Paper 2 will be a mixture of cases, calculations and OSPEs. The subminimum is 50%

5.2 The part II examination, with an overall pass mark of 50% comprises:¹

5.2.1 Two written papers of three hours each. The subminimum is 50% in each paper

Paper 1 (3 hours): 4 x 10 mark questions; 2 x 5 mark questions; 60 Single best answer MCQs with no more than 5 MCQs based on esoteric/specialised expert knowledge

Paper 2 (3 hours): 4 x 10 mark questions; 2 x 5 mark questions; 60 Single best answer MCQs with no more than 5 MCQs based on esoteric/specialised expert knowledge

5.2.2 Practical examination: The practical examination will last over 2 days. The subminimum for the total of all 3 practical components is 45%.

5.2.3 An oral examination: This will be a single oral examination

5.3 EXAMINATION WEIGHTING - FC Path(SA) Part II

Written Theory Papers		Wet Practical	OSPE & Calculations	Clinical Cases	
Paper 1	Paper 2	Practical 1	Practical 2	Practical 3	Oral
20%	20%	20	15%	15	10%

6.0 ADMISSION AS A FELLOW

6.1 Only candidates who have completed training in a CMSA recognised registrar post may be awarded a fellowship if successful in the examination.

6.2 **Candidates who have written the examination as a prerequisite from the HPCSA for inclusion on the specialist register are not eligible to be awarded a Fellowship but will be sent a letter confirming their success in the examinations**

All other candidates will be asked to sign a declaration as below:

I, the undersigned, do solemnly and sincerely declare

that while a member of the CMSA I will at all times do all within my power to promote the objects of the CMSA and uphold the dignity of the CMSA and its members

that I will observe the provisions of the Memorandum and Articles of Association, By-laws, Regulations and Code of Ethics of the CMSA as in force from time to time

that I will obey every lawful summons issued by order of the Senate of the said CMSA, having no reasonable excuse to the contrary

and I make this solemn declaration faithfully promising to adhere to its terms

Signed at this day of

..... 20

Signature

Witness

(who must be a Founder, Associate Founder, Fellow, Member, Diplomate or Commissioner of Oaths)

6.3 A two-thirds majority of members of the CMSA Senate present at the relevant meeting shall be necessary for the award to any candidate of a Fellowship

6.4 A Fellow shall be entitled to the appropriate form of certificate under the seal of the CMSA

6.5 In the event of a candidate not being awarded the Fellowship (after having passed the examination) the examination fee shall be refunded in full excluding HPCSA candidates who are not entitled to a Fellowship.

6.6 The first annual subscription is due one year after registration (statements are rendered annually)

APPENDIX A

1.0 Objectives of the Training Programme:

The objectives of Chemical Pathology training are to produce individuals capable of managing high quality laboratories and of contributing effectively to the investigation and management of patients. Training is designed to attract trainees and maintain their interest – particularly those with the potential to contribute to the advancement of Chemical Pathology

1.1 Trainees will be expected to have a comprehensive knowledge of, and skills in:

- Biochemistry, physiology, general and special pathology
- The biochemical and metabolic basis of disease
- The application of laboratory test results to the investigation and management of patients
- The investigation of clinical and laboratory problems
- The provision of specialist opinion in Chemical Pathology
- Accreditation theory and practice
- Physical and chemical principles of analytical techniques and analytical methods
- Efficient laboratory administration and management skills to provide an effective service
- Data Management and computational skills and knowledge
- Health and Safety requirements for laboratories
- The processes required to do research namely reviewing the literature, writing scientific proposals, writing ethics and grant applications

The ability to critically assess the literature and the ability to draw valid conclusions from the data

2.0 Stages of Training

The duration of the training programme is four years and comprises four stages of training. Training occurs at academic hospitals. The Registrars are obliged to attend relevant clinics throughout the duration of the training programme. The training period demands that registrars rotate through all the various training units encompassing

- general chemistry and automation
- immunochemistry endocrinology and serology
- chromatography
- proteins and special chemistry laboratories. Each unit is led by a pathologist who will supervise and guide training.

Registrars will also be taught to authorise work within the first few months of training and will thereby be exposed to a large variety of different clinical cases as well as obtaining skills and experience in laboratory medicine

2.1 Introductory course:

This six week introductory course aims to expose clinically trained doctors to laboratory practice and encompasses basic laboratory techniques as well as basic chemical pathology

2.2 Primary Training:

This includes the following:

- Biochemistry and biochemical pathways
- Understanding of molecular biology principles and laboratory techniques eg PCR, flow-cytometry and fish etc
- Knowledge of the patho-physiology of disease
- Understanding the principles of laboratory techniques, methods and instrumentation
- Basic knowledge of Chemical Pathology
- Understanding of quality control
- Principles of accreditation
- The ability to review the literature and write a mini review

2.3 Secondary training:

This stage of training encompasses the last two years of the programme. During this time the registrars will attain an in depth knowledge and understanding of the principles of Chemical Pathology. They will develop skills in trouble shooting laboratory problems. They will begin to participate in management issues and attend management meetings. They will attain the skills necessary for independent professional practice as a Chemical Pathologist including the ability to manage a laboratory and to consult independently. Assessment during this time will include oral and written examinations including a workplace based assessment of laboratory techniques. The exit examination being the CMSA FC Path(SA) Chem examination.

3.0 Methods of Assessment during Training:**3.1 Examinations:**

Formative assessments occurs throughout the training period

3.2 Case Presentations:

Each registrar will be obliged to present six cases during the course of every year of training. Each case will be assessed using the following criteria and will form part of the annual formative assessment of the registrar and should also be included in the training portfolio submitted to the College.

- Understanding the theory of the case
- Clinical assessment of the case
- Proposed additional investigations or comment on appropriateness of the investigations performed
- Laboratory issues that could influence the work-up
- Overall summary of the case
- Presentation

3.3 Seminars:

Registrars will be obliged to present a minimum of three seminars per year. The topics of the seminar will be decided by the training co-ordinator and will cover an area of relevance to the registrar and to the training programme as a whole. Each seminar will:

- Require a review of the current literature
- Test the ability of the registrar to understand, summarise and highlight the important issues surrounding the chosen topic
- Assess the presentation skills of the registrar

Each seminar will be assessed using the criteria above.

3.4 Practical skills

Practical skills will be assessed on the following:

- Understanding the principles of the technique or procedure
- Risk assessment
- Ability to evaluate quality control measures
- Ability to perform the procedure
- Ability to trouble shoot the process
- Ability to interpret the data appropriately

4.0 Supervision and Feedback:

Pathologists in charge of the various units will supervise the registrars in accordance to their level of training. Registrar feedback will be given at the end of each rotation. The Pathologist in charge of the unit will sign off all outcomes achieved during the rotation and will write a short feedback report on the progress of the registrar in their log books. Regular inspection of candidates log books will be conducted by Pathologists in charge of the various units A bi-annual appraisal with the head of the Registrar training programme as well as the HOD will be conducted.

5.0 Departmental Meetings

Throughout the programme registrars are obliged to attend and to present at departmental meetings as well as academic meeting in other relevant departments. These include case presentations, journal clubs and seminars. The aim of these sessions is to provide a formal structure for registrars to critically review and appraise the literature, critically assess the experimental design and data analysis of published research and for candidates to present data in public. Furthermore these sessions will also allow candidates the opportunity to learn how to use the library and other IT facilities. The interaction with scientists allows for the exposure to a large variety of research projects and techniques as well as benefiting from their knowledge and experience. Most importantly these sessions also provide an excellent training and teaching forum.

6.0 Teaching and Training Sessions

Regular training and teaching sessions will be conducted in each training unit. The programme will vary from unit to unit and will be determined by the demands of the unit. Training sessions will cover clinical, theoretical and practical aspects of the training unit. Registrars will participate in the Chemical Pathology teaching programme of undergraduate medical students as well as the technologists and technicians. It is anticipated that preparation for these sessions are an excellent mode of learning.

7.0 Practical Techniques Training

Practical training sessions will be conducted throughout the training programme. These sessions will allow the registrar to learn laboratory techniques and will range from using a pipette to performing analyses of different complexities and different methods including enzyme kinetics and PCR etc. The aim of these sessions is to ensure that registrars develop laboratory based skills and have insight into technical laboratory problems

8.0 Clinics

Registrars are obliged to attend clinics and ward rounds on a regular basis. The clinics are associated with the rotational unit:

- General chemistry rotation - Diabetes clinic
- General chemistry rotation - Lipid Clinic
- Immunochemistry rotation - Endocrine clinic
- Manual Bench - Metabolic bone clinic

Should registrars have special interests, eg HIV or haematology oncology, arrangements will be made for them to attend those clinics on condition that the laboratory is adequately staffed and that it does not interfere with other commitments

9.0 Detailed Course Outline ²

9.1 Introductory course:

The aim of this short six week introductory course is to introduce candidates to the basic principles and practice of laboratory medicine.

The following topics are addressed:

9.1.1 Specimen handling

- Including collection, transport and storage
- Use of appropriate tubes
- Understanding the different types of preservatives in tubes and their affect on different assays
- The differences between analysing serum versus plasma
- The effect of different stoppers on assays especially metals
- The effect of gel separator tubes on different assays
- The appropriate use of glass and plastic tubes as well as the tubes used to freeze samples

9.1.2 Principles of laboratory health and safety

(Registrars are encouraged to have a course of Hepatitis B inoculations)

- Registrars are obliged to read the NHLS Health and Safety Manual to ensure they understand the contents of the document and to sign it

9.1.3.../

² Updated curriculum August 2017

9.1.3 Principles of quality control

- The concept of total quality management of a laboratory
- The concept of quality control and how it is managed in the laboratory
- The use and benefits of internal and external quality control
- Patient based quality control
- The basic concepts of laboratory accreditation are introduced

9.1.4 Analytical techniques:

- The use of pipettes and volumetric flasks
- Units of measurement
- The use of scales and weighing of reagents
- The preparation and storage of reagents
- The use and maintenance of centrifuges
- The making up of solutions of different strengths
- The use of pH electrodes and the preparation of buffer solutions
- Enzyme kinetics
- Water quality and purification
- Spectrophotometric methods
- Microscopy

9.1.5 Clinical Chemical Pathology

- Water and electrolytes
- Renal
- Acid base regulation
- Carbohydrate and lipids
- Proteins and enzymes
- Liver and gastrointestinal tract
- Basic endocrinology

9.2 Primary training programme:

The aims of this stage of training is to introduce the candidate to the practice of laboratory medicine including amongst others methodology instrumentation and quality control as well as ensuring that the registrars obtains a solid understanding of biochemistry and pathophysiology of disease. During this phase of training, registrars attend lectures for the MMed part I course which incorporates a molecular biology training course including a literature review of the molecular basis of a specific disease of their choice, as well as lectures that are specifically geared to fundamental principles of biochemistry and chemical pathology. Registrars are continually assessed as to their interpretation of laboratory tests and their ability to comment appropriately on laboratory results in order to contribute to patient diagnosis and management

9.2.1 Basic Laboratory Principles:

- Pre-analytical variables
- Calibration and standardisation
- Reference ranges - approaches to determining reference ranges; namely numbers needed, partitioning requirements and parametric versus non parametric analysis. Challenges associated with reference range setting in both the paediatric and geriatric populations. Common reference ranges - benefits and associated problems; detection of outliers and suitable test; Dixons test; Chauvenet's criteria; Grubbs test
- Principles of method selection
- Principles of instrument selection
- Method validation
- Principles of test and instrument selection
- Basic investigation of an analytical method
- Interferences and interference testing

9.2.2 Quality Control and Quality Assurance:

- How to control the quality of a method
- Laboratory error detection
- Six sigma - pros and cons
- Control materials – ranges, matrices, storage etc
- Levey - Jennings charts and control functions

- Internal quality control programmes .../

- Internal quality control programmes
 - Quality control acceptance rules - eg Westgard
 - Use of external quality assessment programmes - including frequency of testing, matrix of QC material, stability of material, data analysis, number of participants etc
 - Interpretation of interim, end of cycle and sub group QC/QA reports and subsequent course of action
 - Process of selecting appropriate QC procedures and analytical goals
 - Key performance indicators (KPIs)
 - Quality control requirements for laboratory accreditation systems
 - QA as it relates to near patient testing/POCT
 - Verification of qualitative assays
- 9.2.3 **Laboratory Statistics:**
- Normal distribution - parametric versus non-parametric statistics
 - Biological variation and the determination of critical difference
 - Imprecision and coefficient of variation
 - Uncertainty of measurement including combining uncertainties (anion gap)
 - Sensitivity, specificity and predictive values
 - Likelihood and odds ratios and their utility
 - Receiver Operating Characteristic (ROC) Curve analysis and utility
 - Common statistical tests and concepts namely: Confidence intervals, Student's t-test, Wilcoxon signed rank test, Pearson's correlation coefficient, Chi-squared test, the concept of significance, univariate versus multivariate analysis etc
- 9.2.4 **Analytical Methods:**
- Understanding of the principles of instrumentation
- Spectrophotometric methods
 - Ion selective electrodes
 - Turbidimetry
 - Fluorimetry
 - Flame emission photometry
 - Automation
 - Electrochemical methods
 - Osmometry and colligative properties of fluids
 - Enzymology including iso-enzymes, fixed interval and kinetic assays
 - Radiation & RIA
 - Immunochemical methods
 - Immunoassay
 - Electrophoretic methods
 - Chromatography
 - Point of care and dry phase chemistry
- 9.2.5 **Biochemical Aspects of Disease:**
- Biological variability
 - Diseases of the GIT and pancreas
 - Liver disease
 - Protein structure, metabolism and disorders
 - Basic immunology
 - Kidney and urinary tract diseases
 - Pulmonary function
 - Clinical enzymology
 - Mechanisms of inheritance
 - Principles of screening
 - Interferences
 - Effects of drugs on laboratory assays
 - Receptors and cellular signalling

9.2.6 Health and Safety:

- Individual and collective responsibility
- Handling of potentially infectious samples (HIV and hepatitis B)
- Handling of noxious chemicals
- Radiation protection measures
- Mechanical and electrical safety
- Fire precautions
- Dealing with an accident
- Attendance at Laboratory Safety Committee meetings
- Read the Laboratory Safety Manual

9.2.7 Research competencies:

- Registrars are obliged to do a mini-literature review as part of the MMed part one course. This allows for critical review and appraisal of the literature. It also ensures that registrars use library and IT facilities appropriately
- Registrars are obliged to attend a research techniques course which includes lectures in the following:
 - study design
 - basic statistical concepts
 - ethics in research and ethics applications
 - research project and financial management
 - grant application

9.2.8 Basic Concepts in Molecular Biology:

- Scientific writing
- DNA and RNA extraction and analysis
- Mutations, polymorphisms, RFLP's, SNP's
- PCR
- Protein analysis – electrophoresis, western blotting
- Recombinant DNA and proteins
- Detection of polymorphisms
- Analysis of mutations
- Flow cytometry
- Chromosome analysis and FISH
- Microarrays
- Gene manipulation
- Gene therapy
- RNA interference and micro RNA
- Epigenetics
- Genomics, proteomics and metabolomics - indications and laboratory methods
- Protein folding disorders
- Posttranslational glycosylation and associated disorders
- Telomeres

9.2.9 IT skills and knowledge

- Understanding the different laboratory information systems
- The use of databases
- The role of the LIS at different stages in the process of producing results
- Instrument interfaces
- Links to other computers eg patient administration, pharmacy, clinical
- Reporting/authorisation procedures and auto-validation
- Neural-networks - understanding of the processes and the benefits to the laboratory
- Patient identification and methods of ensuring accuracy
- Management statistics from laboratory computers
- Internet and email
- Power-point and Excel, Access use etc

9.2.10 Basic investigation of a method and equipment

- Practicability including: appropriateness for environment, work flow implications, throughput, specimen type, range of analyses, on-board stability, connectivity to LIS, staff requirements, finances etc
- Availability of service and application support
- Optimisation of reaction conditions
- Recognition of critical parameters (robustness) bias, imprecision, sensitivity and specificity
- Investigation of common interferences
- Reference ranges: correct for population and impact on current ranges
- Criteria for acceptability

9.2.11 Method comparison data analysis

- Linear regression analysis
- Weighted and un-weighted Deming analysis
- Passing and Bablock analysis
- Bland Altman difference plots

9.2.12 Practical competancies

- Concepts of molarity and normality
- Interconversion of mass units and molar units
- Acids and bases preparation of buffers
- Titration curves – concepts of pH and Pk
- Solution preparation including the use of a balance, pipettes volumetric flasks measuring cylinders and pH meter
- Understanding the concepts of polar and non-polar compounds and the partitioning of compounds into solvents and solvent extraction
- Cuvettes - different materials and their uses
- Spectrophotometry - principles, filters and monochromators, Beer's law, methods of calibration using holmium and dydinium filters, the use of a scanning spectrophotometer etc
- Molar absorptivity determination
- The measurement of blood gases, the effect of calibration with room air, the changes due to height above sea level, ion selective electrodes
- The measurement of ionised calcium
- Chromatography principles, thin layer chromatography, sugar chromatography, calculation of RF values, protein electrophoresis and potential problems and immunofixation
- Enzymology – enzyme kinetics, Michaelis Menton equation, Km and Vmax determination, Lineweaver Burk plots, measurement of enzyme activity and substrate concentration, rate versus endpoint assays
- Radioactivity - understanding the principles of radioactivity, radio-active decay and safety precautions needed. Ability to interpret radio-immuno assay curves of competitive and sandwich assays. Understanding of the concept of ED50
- Molecular biology – isolation of DNA, PCR, and restriction enzyme digestion

9.3 Secondary Phase

The aim of this phase of training is to:

- Integrate the knowledge acquired in the introductory course and phase A and to apply it to laboratory Chemical Pathology
- Understand the principles of methodology and instrumentation and their influence on assay measurement
- Obtain an in depth knowledge of the pathophysiology of disease and the most efficient manner of investigating and monitoring the disease
- Understand the concepts of quality management and the challenges of quality control
- Acquire a solid knowledge of laboratory safety and its implementation
- Acquire the IT and management knowledge and skills to manage a laboratory successfully
- The ability to interpret laboratory results effectively and to consult with confidence

9.3.1 **Laboratory Competencies**9.3.1.1 **General**

- Have a working knowledge of basic statistics, including calculations of mean, standard deviation, confidence limits, coefficients of variation, limit of blank, limit of detection, limit of quantitation
- Methods of collection, identification and storage of specimens; principles of screening and appropriate testing
- Data manipulation and interpretation
- Theory and practice of reference values, quantities and units
- Laboratory safety including control of chemical, physical microbiological and radiation hazards
- Understanding of the factors that contribute to pre-analytical, analytical and post analytical error
- Understand the principles and practice of quality control procedures
- Internal quality control
- External quality assessment
- Interpretation of QC/QA and subsequent course of action
- Understanding the principles of instrument and method selection including the process of method validation
- The principles surrounding the establishment of reference ranges
- Point of care testing including the various methods, instrumentation, quality control and the management of this process at the bedside

9.3.2 **Analytical techniques/instrumentation – record of practical experience**9.3.2.1 **Aims**

To enable the candidates to understand a wide range of analytical techniques, and methods, and have insight into their performance, comparative usefulness and applications

9.3.2.2 **Objectives**

- To ensure that the candidates is fully conversant with the performance and limitation of widely used methods in clinical biochemistry; that he/she can detect errors and sources of error and will be able to take responsibility for assays
- To ensure that the candidates understands the technology and design of biochemistry analysers and appreciates their limitations and benefits

9.3.3 **Analytical technique/instrumentation**9.3.3.1 **Basic Laboratory Techniques**

- Specimen collection, order of draw, handling and storage
- Types of specimen and application: blood, plasma, saliva, urine, CSF, pleural fluid, ascetic fluid etc
- Post-mortem body fluid samples and chemistry; application in post-mortem testing
- Identification of common spectral interference's
- Methods of standardisation and calibration
- Primary and secondary reference materials
- Definitive reference methods and their hierarchical relationships
- Effects of matrix on calibration
- Primary calibration of equipment eg temperature, volume, molar absorptivity
- Use of pipettes and volumetric glassware
- Preparation and storage of reagents
- Use and maintenance of centrifuges
- Ultra filtration
- Ultra centrifugation
- Problems relating to provision of a paediatric biochemistry service

9.3.3.2 **Spectrometric Methods**

- Beer's Law
- Visible and UV spectrometry
- Bichromatic spectrometry
- Fluorimetry
- Tubidimetry and nephelometry.../

- Turbidimetry and nephelometry
 - Densitometry
 - Derivative spectrometry
 - Luminometry (bio- and chemi-)
 - Linear diode spectrometry
 - Reflectance spectrometry and bilirubinometers
 - Flame emission photometry
 - Nuclear Magnetic resonance (NMR) spectroscopy principles and applications
 - Infra-red spectrometry
- 9.3.3.3 **Automated instrumentation**
- Random access analysers
 - Immunoassay analysers
 - Centrifugal analysers
 - Pipetting work stations
 - Other discrete analysers
 - Continuous flow (including flow injection)
 - Elementary robotics and modular systems
- 9.3.3.4 **Electrometric Methods**
- Nernst equation
 - Ion selective electrodes Na⁺, K⁺, Cl⁻
 - pH, pO₂, pCO₂ electrodes
 - Polarographic oxygen electrodes eg glucose
 - Hydrogen peroxide electrodes
 - Other ISE e.g. Ca²⁺, NH₄⁺, Mg²⁺, Li⁺
 - Field effect transistor technology
 - Non invasive measurements
- 9.3.3.5 **Osmometry**
- Colligative properties of fluids
 - Calculation of the osmolality and the osmolar gap
- 9.3.3.6 **Enzymology**
- Fixed interval assays
 - Kinetic assays
 - Isoenzyme fractionation/quantitation
 - Tissue enzymes
 - Use of enzymes as reagents
 - Macro-enzymes
- 9.3.3.7 **Radioisotope**
- Different types of radioactive decay used in the clinical laboratory
 - Use of radio isotopes as labels in immunoassay analyses
 - Safety measures when using radioactivity
- 9.3.3.8 **Immunochemical Techniques**
- Immunoelectrophoresis
 - Immunofixation
 - Immunodiffusion
 - Competitive radioimmunoassay
 - Immunoradiometric assays
 - Electroimmunoassay
 - Enzyme labels
 - Fluorimetric labels
 - Chemiluminescent labels
 - Interferences and heterophile antibodies
 - Principle of fluorescent polarization immunoassay (FPIA)
 - Measurement of free hormone concentrations
 - Comparison of CEDIA, EMIT and ELISA assay methods

- 9.3.3.9 **Electrophoretic Techniques**
- Principle of electrophoresis
 - Principle of immunofixation
 - Ampholytes and their uses
 - Cellulose acetate
 - Agarose gel
 - PAGE using SDS and gradient gels
 - Isoelectric focusing
 - Silver and gold stains
 - Capillary zone electrophoresis
 - 2D electrophoresis
 - Automated electrophoresis systems
 - Electroendosmosis
- 9.3.3.10 **Chromatographic Techniques**
- Principle of Chromatography
 - Theoretical plates and their uses
 - Sample preparation (eg desalting, liquid extraction, derivitisation)
 - Gel exclusion chromatography
 - Thin Layer chromatography - TLC
 - Columns (ion exchange, affinity etc)
 - GC principles and detectors including MS
 - HPLC principles and detectors eg. UV, fluorescent, electrochemical
 - Normal phase and reverse phase chromatography
 - Diode array
 - Principles of HPLC- MSMS and MALDI-TOF•
 - Detector systems
- 9.3.3.11 **Atomic absorption spectroscopy**
- Flame
 - Furnace
 - Other
- 9.3.3.12 **DNA/RNA/Chromosomal analyses**
- DNA extraction
 - RNA extraction
 - PCR
 - Southern blotting
 - Northern Blotting
 - Western Blotting (proteins)
 - FISH
 - Other techniques – Next generation sequencing vs conventional sequencing
- 9.3.3.13 **Point of Care (POCT)**
- Analytical methods - dry and wet chemistry, including reflectance photometry, ion selective electrodes, electrochemical devices, spectroscopy, dipstick technology, thin film technology, immobilised enzymes etc
 - Quality assurance
 - Equipment validation and comparison
 - Connectivity to LIS
 - Stock control and monitoring
 - Varying blood collections including capillary venous and whole blood and adaptations to routine lab reference ranges
 - Staff training
 - Safety
- 9.3.3.14 **Dynamic Function Tests** – procedures and interpretation

9.3.3.15 Calculations in the Clinical Chemistry laboratory

- Units and their manipulation
- Lab manipulations (conversions dilutions etc)
- Acid base, pH and buffers
- Spectrophotometry
- Renal function
 - Creat clearance,
 - eGFR calculations
 - TTKG,
 - TmP/GFR
 - Osmolar and free water clearance
 - Fractional excretion
 - K_{tv}
 - Osmolality
- Basic pharmacokinetics
- Enzymology
- Body fluid and electrolytes
 - Correct of Na for hyperglycaemia
 - Fluid loss calculation
 - Direct vs indirect ISE
- The basis of statistics
 - Mean, SD , CV, Z -score
 - Analysis of means and variance
 - T test, std error of the mean, ANOVA
 - Correlation and regression
 - Clinical utility of lab tests
 - Sensitivity
 - Specificity
 - PPV, NPV
 - Odds ratio
 - Probability
 - Statistical power
- Miscellaneous
 - HPLC calculations
 - RIA calculations
 - Genetic risk calculations, including Hardy-Weinberg equilibrium
 - Half-lives and decay
 - Error grid analysis
 - Calculations in total parenteral nutrition

9.3.4 Theoretical syllabus**9.3.4.1 Competencies in Chemical Pathology of Disease****9.3.4.1.1 Biological variability**

- Effect of genetic and environmental influences such as age, sex, nutrition, time of day, stress, posture, hospitalisation and therapeutic agents on biochemical results
- Reference values and population statistics
- Common reference intervals
- Inter and intra-individual variation
- Assessment and applications of biological variance in setting analytical goals
- Assessing utility of reference values
- Significance of changes in serial results

9.3.4.1.2 **Water and Electrolytes**

- Distribution of water and electrolytes
- Regulation of extra cellular fluid osmolality and volume
- Antidiuretic hormone
- Renin-angiotensin-aldosterone system
- Natriuretic peptides
- Water depletion and excess - biochemistry and methods of investigation
- Sodium depletion and excess: algorithmic approach to hypo-and hypernatraemia
- Measurement of sodium-direct and indirect methods
- Syndrome of inappropriate anti-diuretic hormone - clinical and biochemical features
- Diabetes insipidus- biochemical features and laboratory diagnosis. Effect of hormones and drugs
- Osmolar gap - definition, calculation and use
- Intracellular electrolytes and their measurement

9.3.4.1.3 **Pottassium**

- Hypo – and – hyperkalaemia - clinical presentation, pathophysiology, laboratory approach and investigation
- Artefactual causes of hyperkalemia
- Methods of potassium measurement

9.3.4.1.4 **Principles of intravenous fluid therapy administration**

- Constituents of different fluids
- Indications for the use of the various fluids
- Complications of intravenous fluid administration

9.3.5 **Acid-base**

- Physiology of normal respiration - An understanding of Stewart's approach to acid base physiology and the manner in which it differs from the classical approach
- Transport of O₂ and CO₂
- Respiratory and renal mechanisms in acid-base regulation
- Respiratory diseases
- Principle types of acid-base disturbance and their causes
- Assessment of acid-base disturbance
 - Measurement of H⁺
 - Measurement of pCO₂
 - Measurement of pO₂
- The concept of actual bicarbonate, standard bicarbonate and base excess
- Anion gap – calculation and its value in the assessment of acid base disturbances. Causes of a normal and high anion gap metabolic acidosis.
- Principles of pulse-oximetry and other determinants and assessment of tissue oxygenation
- Acid-base changes in hypothermic patients and how it should be monitored and interpreted
- Pathophysiology and laboratory diagnosis of renal tubular acidosis

9.3.6 **Renal**

- Renal physiology
 - Glomerular filtration
 - Tubular function
 - Water homeostasis
 - Hydrogen ion homeostasis
 - Renin-angiotensin system
 - Erythropoietin
 - Kallikrein-kinin system
- Differentiation of pre-renal and renal uraemia
- The use of a dipstick in the diagnosis of renal disease
 - Biochemistry and diagnosis of acute and chronic renal failure.../

- Biochemistry and diagnosis of acute and chronic renal failure
- The use of creatinine, cystatinC, and calculations such as Cockcroft Gault, MDRD and -CKD to determine GFR
- Acute-on-chronic renal failure
- Laboratory assessment of acute kidney diagnosis
- Glomerulonephritis causes and biochemical diagnosis
- Renal bone disease pathophysiology, laboratory diagnosis and monitoring
- Renal glycosuria
- Pathophysiology and biochemical presentation of Fanconi syndrome and other renal tubular defects, RTA, Barter's Syndrome, Gittelmans syndrome etc. and the associated laboratory tests including tubular function tests
- The kidney as an endocrine organ
- The nephrotic syndrome - patho-physiology, etiology, biochemical diagnosis

9.3.7 **Urine analysis**

- Normal and abnormal urine compositions
- GFR -urine and serum measurement of creatinine
- Renal handling of proteins, proteinuria, methods of analysis including POCT and differentiation of glomerular versus tubular proteinuria
- Microalbuminuria – definition, pathophysiology (both old and new concepts) clinical value and methods of measurement
- Abnormal pigments and crystals and their implications
- Urinary casts and their significance
- Myoglobin- and haemoglobinuria-diagnosis and measurement
- Differential diagnosis of red-urine
- Urinary electrolytes, calcium, uric-acid and osmolality – clinical benefits and associated methods
- Bence-Jones proteins - methods of detection and clinical significance
- The laboratory assessment of renal function
 - Measurement and calculation of glomerular filtration rate (GFR)
 - Plasma markers of renal function
 - Measurement of renal plasma flow
 - Tubular function tests

9.3.8 **Renal replacement therapy**

- Assessment of dialysis adequacy
- Renal transplantation
- Renal transplant - laboratory monitoring and immunology. Markers of transplant rejection

9.3.9 **Renal Calculi**

- Pathophysiology and composition of renal calculi- current theories
- Methods of analysis of renal calculi
- Diagnosis, investigation and monitoring of patients with renal calculi

9.3.10 **Diabetes Mellitus and hypoglycaemia**

- Carbohydrate metabolism and glucose regulation
- Glucose measurement including POCT methods and the associated problems
- Classification aetiology of diabetes
 - Type 1 diabetes
 - Type 2 diabetes
 - MODY
 - Insulin resistance syndromes including the metabolic syndrome-diagnosis pathophysiology and clinical presentation
 - Gestational diabetes - diagnosis and risks to fetus and mother
 - Glucose tolerance test (GTT)-precautions, procedures and interpretation
 - Antibody tests in diabetes – antiGAD, anti insulin etc - methods of measurement and interpretation
 - Endocannabinoid pathway

- Complications of diabetes.../

- Complications of diabetes
 - Diabetic ketoacidosis – pathophysiology and biochemical changes
 - Hyperosmolar coma diagnosis and biochemical investigation
 - Pathophysiology of diabetic complications
 - Laboratory investigation and monitoring of patients for glycaemic control and detection of complications eg nephropathy and retinopathy and lipid abnormalities
 - Microalbuminuria its measurement and role in the management of diabetes
- Principles of treatment of diabetes
- Glycated haemoglobin and glycated proteins eg fructosamine
 - Methods of measurement of HbA
 - Glycated Hb and glycated albumin's role in the monitoring of diabetic patients
 - Standardisation of the measurement of glycated haemoglobin
 - Glycated proteins and their role in the pathophysiology of diabetic complications
- Hypoglycaemia
 - Definition, causes and laboratory investigation of hypoglycaemia in the adult
 - Non-islet cell tumour hypoglycaemia and the role of IGF-II
 - Insulinoma – pathophysiology and laboratory diagnosis
 - Factitious hypoglycaemia- laboratory investigation
 - Differential diagnosis and investigation of hypoglycaemia in an infant and child
 - Assays for insulin, pro-insulin and insulin antibodies their uses

9.3.11 Enzymology

- Factors influencing enzyme stability and induction
- Isoenzymes -structural basis, separation and quantitation
- Clinical role, indications and methods for the analysis of the following isoenzymes:
 - Alkaline phosphatase
 - Lactate dehydrogenase
 - Amylase and lipase
 - Aminotransferases
 - Angiotensin converting enzyme
 - Creatine kinase
 - Lactate dehydrogenase
 - Gamma-glutamyl transferase
 - Cholinesterase and variants
- Enzyme replacement therapy - indications
- Macroenzymes
 - Clinical relevance
 - Methods of detection

9.3.12 Proteins

- Properties, functions and measurement of the principal proteins of plasma including:
 - Albumin
 - Protease inhibitors
 - Transport proteins
 - Ceruloplasmin
 - Clotting factors
 - Complement
 - Immunoglobulins
- Hypoalbuminaemia and its investigation
 - Causes
 - Pathophysiology of oedema due to low albumin levels
- Paraproteinaemias and their investigation
 - Diagnosis and monitoring
 - Bence-Jones proteins
 - Diagnosis and clinical significance of MGUS
 - Waldenstroms macroglobulinaemia and the hyperviscosity syndrome
 - Cryoglobulinaemia: Clinical presentation and laboratory investigation
 - And viscosity measurement.../

- and viscosity measurement
 - Light chain disease
 - Heavy chain disease
 - Light chain measurements and role in the diagnosis and monitoring of myeloma
 - Prognostic markers
- Plasmapheresis – principles and utility in the management of certain diseases
- Immunoglobulin deficiencies including subclass
- Alpha-1-antitrypsin deficiency and protein folding disorders biochemical investigation and clinical presentation
- Acute Phase Proteins
 - Pathophysiology
 - The effect of the acute phase response on the interpretation of laboratory results
- CRP and its role as a marker of inflammation and a risk factor for coronary artery disease
- Procalcitonin: biochemistry, measurement and role in the management of infections
- Interleukins: Role in the inflammatory pathway and usefulness in the detection and monitoring of infection and inflammation

9.3.13 Proteinuria

- Renal handling of proteins
- Causes and pathophysiology of proteinuria in health and disease
- Different methods for measuring proteinuria
- Microalbuminuria clinical significance and methods of detection

9.3.14 Fluids Pleural and Peritoneal

- Biochemical profiles that distinguish transudates from exudates in pleural and peritoneal fluids-Lights criteria
- Chylous pleural effusion- pathophysiology and laboratory diagnosis
- Amylase, tumour markers and other analytes in fluid

9.3.15 Cerebrospinal Fluid

- CSF protein -Clinical significance and methods of analysis
- CSF Xanthochromia causes and laboratory diagnosis
- CSF oligoclonal banding- mechanisms of detection and clinical significance
- Measurement of CSF glucose, chloride, lactate and bilirubin - clinical significance and relevant methods
- Neopterin and NSE in CSF as markers of disease
- The use of CSF for the diagnosis of a sub-arachnoid haemorrhage
- Methods of differentiating CSF from nasal fluid in patients with base of skull fractures
- Multiple Sclerosis, it's pathophysiology and diagnosis including the use of myelin basic protein
- Alzheimers Disease. Pathophysiology and diagnosis

9.3.16 Gastrointestinal tract

- Physiology and biochemistry of digestion
- The gut as an endocrine organ: gastrointestinal hormones and associated disorders
- Clinical presentation, laboratory investigation and diagnosis of:
 - Peptic ulcer
 - Zollinger Ellison syndrome
 - Pyloric obstruction
 - Cystic fibrosis
 - Pernicious anaemia, B12 and folate deficiency
 - Pancreatitis (Acute and chronic)
 - Malabsorption
 - Lactose intolerance
 - Coeliac Disease
 - Lactose intolerance
 - Acute and chronic pancreatitis - prognostic criteria
 - Inflammatory bowel disease
 - Disaccharidase deficiency.../

- Disaccharidase deficiency
- Gastrointestinal malignancy
- Cacinoid syndrome
- Peptide secreting tumours of the entero-pancreatic system
- Macro-amylase and other causes of a persistently increased amylase level
- Helicobacter Pylori – clinical significance and methods of detection including breath tests and serology

9.3.17 **Methods of studying gastric secretion**

- Gastric stimulation tests using pentagastrin, secretin and calcium loading tests
- Assessment of pancreatic functions

9.3.18 **Malabsorption and maldigestion**

- Clinical presentation
- Biochemical abnormalities
- Laboratory assessment – Xylose absorption, Shilling tests breath tests, intrinsic factor and bile-acids
- Investigation of chronic pancreatic dysfunction by tubeless tests and immuno-reactive trypsin
- Serological markers of coeliac disease
- Measurement of faecal fat

9.3.19 **Faecal analysis – the use and measurement of the following**

- Occult blood and other tests used for the screening of colorectal cancer eg faecal albumin etc
- Fat
- Nitrogen balance studies
- Faecal osmotic gap in the investigation of chronic diarrhea
- Faecal elastase
- Faecal calprotectin as marker of inflammatory bowel disease

9.3.20 **Liver**

- Functions of the liver
- Proteins produced and secreted by the liver, including Fetuin-A
- Formation of bilirubin
- The different fractions of bilirubin present in serum, the methods of their detection and the clinical usefulness of their measurement
- Enterohepatic circulation, bile salts their clinical relevance and their measurement
- Biochemical assessment of hepatic function/integrity and the associated methods
- Liver function tests - their utility in the diagnosis of liver abnormalities and the methods used for their analysis
 - Delta -bilirubin
 - Prothrombin time
 - Ammonia
 - Alpha-fetoprotein
 - Urobilinogen
 - Ammonia relevance in neonatal period, childhood and in adults
 - MEGX and other tests to assess liver function
- Jaundice in the adult - clinical presentation and laboratory diagnosis
 - Familial hyperbilirubinaemias
 - Gilberts Disease, Dubin Johnson, Rotor
 - Hepatitis due to infective causes, toxins, alcohol, adverse drug reactions
 - Haemolytic jaundice
 - Obstructive jaundice
- Clinical presentation and laboratory diagnosis of diseases of the liver
 - Viral hepatitis
 - Non alcoholic liver disease NASH /NAFLD including pathophysiology
 - Autoimmune hepatitis and associated markers
 - Ischaemic hepatitis

- Cirrhosis.../

- Cirrhosis
- Primary biliary cirrhosis
- Haemochromatosis
- Wilson's disease
- Drug hepatotoxicity
- Alcoholic hepatitis and cirrhosis
- Biliary obstruction
- Gall stones and their composition
- Hepatoma
- Liver metastases
- Reye's syndrome
- Hepatic failure and encephalopathy
- Hepato-renal and hepato cardiac syndromes
- Liver fibrosis – noninvasive assessment Test panels eg Fibrotest
- Liver transplantation
- Laboratory assessment prior to transplant
- Post transplant assessment - acute and chronic phase

9.3.21 Lipids and cardiovascular system

- Cholesterol, LDL HDL and triglyceride metabolic pathways and their interaction with that of carbohydrate metabolism
- Lipoprotein - structure, role in the pathophysiology of atherosclerosis and measurement challenges
- Lipoproteins and their role in lipid metabolism
- Apo-proteins and their role in lipid metabolism
- Inherited and acquired hyper- and hypo-lipoproteinaemias and their metabolic and genetic basis
- Laboratory investigation and principles of management of hyperlipidaemic states
- Atheroma, coronary heart disease and associated risk factors
 - Pathophysiology of CAD as a inflammatory disease
 - The role of oxidative stress in the pathophysiology of CAD - The French Paradox
 - High sensitivity CRP as a risk factor for ischaemic heart disease
 - Homocysteine as a risk factor for ischaemic heart disease
 - Acute coronary syndrome and its diagnosis
 - Pathophysiology of the reperfusion syndrome
- Biochemical markers of myocardial infarction including the new markers such as fibrinogen, ischaemic modified albumin and PAPP-A etc. Indicate the time course of marker elevation
- Troponin- Methods of measurement, standardisation and interferences.
 - Differences between Troponin I and T
 - The use of more sensitive assays
 - Non-ischaemic causes of elevated cardiac troponin
 - The effect of renal failure on Troponin levels
 - The use of Troponin as a prognostic marker
 - Markers of reperfusion
- BNP its use as marker in the management of myocardial infarction
 - The role of BNP in the diagnosis and management of heart failure
 - Factors that influence plasma/serum levels of BNP
 - Differences between BNP and NT-BNP
- Atrial natriuretic peptide
- Hypertension – the role of the laboratory in the investigation and management

9.3.22 Calcium and Bone disease, Magnesium, Phosphate

- Calcium, phosphate and magnesium homeostasis
- Regulation of serum calcium levels the role of PTH, vit D, calcium sensing organs, calcitonin etc
- Methods of measurement of calcium, phosphate and magnesium
- Osteoporosis – Pathophysiology of primary and secondary osteoporosis
 - Role of the laboratory in diagnosis and monitoring
 - of osteoporosis using metabolic bone markers- their pros and cons
- Renal osteodystrophy
- Role of bone markers such as osteocalcin
- Paget's disease
- Hyper and hypo-parathyroidism
- Hyper and hypocalcaemia - clinical presentation, causes and laboratory investigation
- Disorders of phosphate balance – Phosphatonins - their role in the regulation of phosphate metabolism
- Osteomalacia and Rickets – classification, pathophysiology and laboratory diagnosis
- Tumor induced osteomalacia (oncogenic rickets) - Biochemistry
- Disorders of magnesium balance (hyper - and hypomagnesemia) and their investigation including the associated methods
- PTH – actions and regulation of secretion
- Assays for the measurement of PTH in blood, their differences and indications for use
- PTH related peptide (PTHrP) its uses and measurement
- Vitamin D – metabolic pathway, functions, forms found in plasma, their measurement and indications for measurement, and reference ranges. Functions of vitamin D **not** related to calcium and bone metabolism
- Biochemical investigation of osteogenesis imperfecta and fibrous dysplasia

9.3.23 Haemoglobin and porphyrins

- Iron metabolism and the regulation of iron status
- Iron deficiency anaemia and its investigation
- The use of ferritin, iron, transferrin, transferrin receptor measurement, ratios of the above indices and reticulocyte haemoglobin for the diagnosis
- Anemia of chronic disorders - pathophysiology, causes and laboratory diagnosis
- Vitamin B12 and Folate deficiency as a cause of anemia
- Physiology of Vitamin B12 absorption and storage
- Tests for the measurement of vitamin B12 eg Schillings test
- Methods for the measurement of Vitamin B12 and their performance
- Haemochromatosis and non HFE - iron overload syndromes Clinical presentation, pathophysiology, genetics and laboratory investigation
- Abnormal haemoglobins
 - Methaemoglobin and Sulphaemoglobin – Pathophysiology, associated diseases, and methods of detection
- Thalassaemias and sickle cell disease ,metabolic basis, role of the chemistry laboratory in treatment and monitoring
- Red cell enzyme defects

9.3.24 The Porphyrins

- Haem biosynthetic pathway indicating the enzyme defects associated with the various porphyrias
- Acute porphyria – Associated enzyme defects, clinical presentation, pathophysiology, laboratory diagnosis and monitoring, and treatment
- Methods for the measurement and detection of porphyrins and their precursors
- Porphyria cutanea tarda - clinical features, precipitants, associated diseases and biochemical abnormalities
- Erthroporphyrins - clinical presentation and laboratory diagnosis
- Porphyrinuria - differential diagnosis
- Blood porphyrins for the diagnosis of diseases other than porphyria
- Mutational analysis as a means of family screening

9.3.25 Purine and Pyrimidine Metabolism:

- Metabolism of uric acid
- Gout - pathophysiology, laboratory approach to its investigation and measurement of uric acid
- Inborn errors of uric acid metabolism (Lesh- Nyhan syndrome)

9.3.26 Endocrinology**9.3.27 General Principles**

- Feedback mechanisms and endocrine control and rhythms
- Mechanisms of action of steroid, protein and thyroid hormones, hormone receptors and second messengers and illnesses associated with their defects
- Principles of immunoassays and the benefits and liabilities of the different “tags”
- Dynamic function tests principles and interpretation
- Prostaglandins
- Ectopic endocrine tumours – diagnosis
- Nuclear medicine scans and x-rays in the diagnosis of endocrine disorders
- Role of endocrine disruptors in pathology

9.3.28 Hypothalamus

- The role of hypothalamic releasing and inhibiting factors

9.3.29 Pituitary

- Physiology and clinical presentation and effect of pathology of anterior and posterior pituitary
- Panhypopituitarism – clinical presentation and biochemical diagnosis
- Growth hormone and ACTH methods of analysis and standardisation
- The investigation of a child with short stature
- IGF-1 and IGF-BP-3 in the diagnosis and management of patients with growth defects
- Growth hormone replacement therapy its uses in adults and children
- Acromegaly clinical presentation, laboratory diagnosis
- Low libido – causes and investigation
- Prolactinoma clinical presentation and laboratory diagnosis
- Macroprolactin - diagnosis and methods of detection
- Polyuria diagnosis and laboratory investigation.
- Diabetes insipidus pathophysiology and diagnosis
- Dynamic function testing of pituitary reserve
- Isolated pituitary hormone deficiencies and
- Peri-and Post-operative laboratory monitoring of the patient after transsphenoidal pituitary surgery; role of inferior petrosal sinus sampling

9.3.30 Adrenal cortex

- Adrenal steroid production pathway
- Congenital adrenal hyperplasia - clinical presentation of the different forms and biochemical and genetic approach to the diagnosis
- Cushing’s syndrome and its investigation
- Addison’s disease clinical presentation, laboratory investigation and diagnosis
- Conn’s syndrome clinical presentation and laboratory investigation
- DHEA-S adrenal tumors and pharmacological use
- Low renin hypertension and the measurement of rennin
- Measurement of adreno-cortical hormones including pre-analytical considerations

9.3.31 Adrenal medulla

- Catecholamine synthetic pathway
- Pheochromocytoma including the hereditary syndromes - clinical presentation, genetic testing and diagnosis
- Neuroblastoma clinical presentation and laboratory diagnosis
- Incidentaloma- clinical significance and biochemical approach
- MEN I and MEN II syndromes
- Hydroxy-tyramine - measurement and associated pathology
- Interpretation of plasma metanephrines and catecholamines and their urinary metabolites namely urine metanephrines and VMA

9.3.32 Hypertension

- Laboratory approach to the diagnosis of endocrine causes of hypertension
- The biochemical monitoring of hypertensive patients

9.3.33 Thyroid

- Thyroid physiology and iodine metabolism
- Tests for the diagnosis of thyroid disorders and the associated methods:
 - The challenges associated with free hormone measurement
 - The appropriate use of TSH, fT4 and fT3 tests in the investigation of thyroid disorders
 - TSH methods and sensitivities in the diagnosis of thyroid disease
 - The effect of drugs on thyroid hormone measurement and thyroid hormone production
 - Interferences
- Goitre – the role of the laboratory in its investigation
- Hypothyroidism including congenital hypothyroidism
- Thyroid autoimmunity
- Thyroid Hormone resistance syndromes - clinical presentation pathophysiology and laboratory diagnosis
- Iodine deficiency
- Sub-clinical hypo - and hyperthyroidism – laboratory diagnosis
- The effect of drugs and illness on thyroid function tests – Sick euthyroidism
- Thyrotoxicosis - causes and diagnosis, including thyroid antibody tests (namely TSH - receptor antibodies, anti microsomal antibodies) and monitoring
- The use of radioactive iodine for in vivo studies
- Problems of interpretation of thyroid function tests
- Thyroid cancer - laboratory monitoring of patients by means of thyroglobulin and thyroglobulin antibodies
- Neonatal hypothyroidism – causes, screening tests and methods of diagnosis
- Thyroid hormones and pregnancy - changes and measurement
- Post partum thyroiditis - clinical presentation and laboratory diagnosis

9.3.34 Gonads

- The pituitary gonadal axis
- Sexual differentiation
- The menstrual cycle and the use of day 21 progesterone for ovulation prediction
- Amenorrhoea - causes and laboratory investigation
- Testicular failure clinical presentation, causes and laboratory investigation
- Metabolism of testosterone
- Measurement of testosterone in women and children
- Free testosterone - indications for use and laboratory measurement
- Premature ovarian failure - laboratory diagnosis
- Menopause physiology hormonal changes and the value of biochemical diagnosis and monitoring
- Hormone replacement therapy
- Polycystic ovarian failure clinical presentation and diagnostic criteria
- SHBG its use and factors that affect its levels
- Hirsutism – clinical diagnosis and laboratory investigation
- Gynaecomastia - precipitating factors and laboratory investigation
- The investigation and management of male and female infertility
- Intersex

9.3.35 Disorders of growth and development

- Ambiguous genitalia – clinical approach and laboratory investigation
- Precocious puberty
- Delayed puberty
- Disorders of growth
- Growth hormone deficiency and excess and issues surrounding the measurement of growth hormone

9.3.36 Pregnancy, contraception and hormone replacement therapy

- Pregnancy: physiology, complications, detection
- Oral contraceptives and their metabolic effects
- Use HCG for the diagnosis of pregnancy
- Tests of feto-placental function
- Screening for Down's syndrome in the first and second trimesters and other fetal malformations - associated methods including CVS, blood tests, amniotic fluid, detection of fetal DNA in maternal serum and chromosomal analysis; statistical methods, Multiple of the Median (MOM) and application
- Hydatidiform mole and choriocarcinoma biochemical diagnosis and monitoring
- Liver disease in pregnancy - laboratory diagnosis and clinical presentation
- Pregnancy related changes in biochemical laboratory parameters
- Ectopic pregnancy
- Pre-eclampsia, pathophysiology and the role of the laboratory in its diagnosis and monitoring
- Postpartum thyroiditis
- Biochemistry related to in-vitro-fertilisation including assessment of ovarian reserve, time of ovulation, semen analysis etc
- Ovarian hyper-stimulation syndrome clinical presentation and laboratory diagnosis

9.3.37 Amniotic Fluid

- Formation and composition of amniotic fluid
- Monitoring of amniotic fluid for Rhesus haemolytic disease of the newborn
- Screening of amniotic fluid for Downs and other congenital abnormalities
- The risks and benefits of amniotic fluid analyses versus that of chorionic villus sampling
- Alpha fetoprotein and acetylcholine esterase in amniotic fluid as markers of fetal disease
- Fetal lung maturity testing

9.3.38 Neonatology

- An approach to common biochemical problems in the neonate:
 - Fluid balance disturbances
 - Acid-base disorders of the newborn
 - Neonatal jaundice - Physiological and pathological causes and biochemical abnormalities
 - Neonatal hypoglycaemia clinical and biochemical approach to the investigation and diagnosis of ketotic and non-ketotic hypoglycaemia
 - Disorders of calcium and phosphate homeostasis; metabolic bone disease
 - Hypomagnesaemia
 - Application of cord blood for screening in the neonate

9.3.39 Inborn errors of metabolism (IEM)

- Trainees are not expected to have in-depth knowledge of all inherited metabolic defects but should be aware of the major categories of defects: how they present and are investigated; mechanisms of inheritance; the principles of treatment; and the scope of prenatal diagnosis
- Approach to the laboratory diagnosis of an inborn error of metabolism - appropriate tests
- Prenatal diagnosis of IEM
- Quantitative and qualitative enzyme abnormalities occurring in genetic disorders
- The biochemical consequences of a primary enzyme block in a metabolic pathway and the way in which clinical and pathological signs may be produced
- An approach to the diagnosis of inborn errors of metabolism
- Newborn screening- criteria for the selection of tests, the appropriate collection times and analytical methods
- Methods of treatment, particularly by:
 - Dietary manipulation
 - Vitamin supplementation
 - Medical therapy
 - Prevention of infection and other stressors
- Biochemical monitoring of treatment

- Amino acid disorders.../

- Amino acid disorders especially those involving:
 - Phenylalanine
 - Tyrosine
 - Branch chain amino acids and maple syrup urine disease
 - Methionine and homocystine
 - Transport disorders, cystinosis, cystinuria and Hartnup disease
- Carbohydrate disorders including
 - Glycogen storage diseases
 - Galactosaemia
 - Hereditary fructose intolerance and essential fructosuria
- Urea cycle defects
- Organic acid disorders
- Lysosomal and peroxisomal storage disorders
- Mitochondrial disorders
- Purine and pyrimidine disorders (including primary and secondary hyperuricaemias)
- Inherited defects in Vitamin B12 metabolism
- Cystic fibrosis
- Analytical methods for the analysis of samples for the diagnosis and monitoring IEM including: dried blood spots, amino acid and organic acid analysis by means of HPLC, HPLC-MS/MS. GC-MS, oligosaccharide electrophoresis, fibroblast cultures and enzyme analysis, mutation analysis etc

9.3.40 Paediatrics

- Neonatal jaundice – clinical approach and laboratory investigation
- Cystic fibrosis - pathophysiology, laboratory diagnosis and monitoring
- Tumours of childhood - neuroblastoma, nephroblastoma, hepatoblastoma – biochemical diagnosis and monitoring
- Disorders of calcium metabolism in childhood
- Hypoglycaemia - clinical approach and laboratory investigation
- Proteinuria in childhood - clinical approach and laboratory investigation

9.3.41 Nutritional disorders:

- Protein-energy and energy malnutrition - Marasmus and kwashiorkor clinical presentation and related biochemical and haematological changes
- Protein markers of nutritional status Nitrogen balance
- The “re-feeding” syndrome- associated biochemical changes
- Vitamins-
 - Requirements, sources , functions and metabolism
 - The effects and investigation of vitamin deficiency or excess
 - Measurement of vitamins by means of direct and indirect methods
 - Vitamin reference ranges and the associated problems and challenges
- Essential trace elements:
 - Functions, requirements,
 - Clinical presentation of deficiency and toxicity,
 - Laboratory diagnosis and measurement – iron, cobalt, zinc, copper, manganese, selenium, molybdenum, chromium, nickel and vanadium
- Nutritional support- parenteral and enteral nutrition – biochemical monitoring and changes in laboratory results
- Obesity - pathophysiology
- Metabolic syndrome - pathophysiology, clinical diagnosis and biochemical changes

9.3.42 HIV

- Pathophysiology and diagnostic tests
- Biochemical and endocrine changes associated with HIV and anti retroviral therapy
- HIV related renal disease HIVIC and HIVAN
- Lipodystrophy
- Lactate measurement and interpretation in patients on ARV therapy

9.3.43 Neurological diseases and psychiatric diseases

- General understanding of disease of the nervous system
- Biochemical tests profile for the diagnosis of stroke - is it of benefit
- Sub-dural haematomas - biochemical tests
- Biochemical and metabolic abnormalities which present with psychiatric and neurological problems eg hypothyroidism, porphyria electrolyte disorders, Vitamin B12 deficiency etc
- Pathophysiology and laboratory tests in the diagnosis and monitoring of the following:
 - Multiple sclerosis
 - Myasthenia gravis
 - Muscular dystrophy's
 - Parkinson's disease
 - Alzheimer's disease

9.3.44 Autoimmune and Rheumatological diseases:

- The immune response, antibody production and the complement pathway
- The use of auto-antibodies including anti-CCP, rheumatoid factor and anti-nuclear factor amongst others in the diagnosis and monitoring of patients with Rheumatoid arthritis and other autoimmune diseases.
- The use of CRP in the diagnosis and monitoring of autoimmune diseases
- Anaphylaxis - patho-physiology, mast cell tryptase and C1-esterase deficiency.
- Pharmacogenetics and drugs used to treat autoimmune disorders
- Malignant Hyper thermia
- Disorders of collagen metabolism

9.3.45 Alcohol:

- Pathways of alcohol metabolism
- Laboratory tests for the diagnosis of acute and chronic alcohol abuse
- Methods for the measurement of alcohol including breath and blood analyses
- Carbohydrate deficient transferin and its role in the diagnosis and monitoring of chronic alcohol abuse
- Laboratory test for the diagnosis and monitoring of complications of chronic alcohol abuse

9.3.46 Tuberculosis (TB):

- Pathophysiology of Tuberculosis
- The role of the chemical pathology laboratory in the detection and monitoring of Tuberculosis and its complications including adenosine deaminase measurement (ADA)

9.3.47 Cancer and Tumour Markers:

- The nature of malignancy and tumour growth including the cell cycle defects, oncogenes, tumour suppressor genes and DNA repair genes.
- Familial cancer Syndromes - namely BRCA, MEN I and MEN II, retinoblastoma
- Common malignancies of adulthood
- Malignancies of childhood in which biochemical tests have a role (neuroblastoma, hepatoblastoma, teratoma)
- Biochemical effects of cancer and its treatment
- Tumour markers their relation to tumour biology, and their use for screening, diagnosis assessing prognosis and monitoring of malignancies
- The properties and measurement of specific markers
- AFP, CEA, HCG, CA19-9, CA 125, AFP, PSA, VMA, plasma metanephrines, 5-HIAA, chromogranin A, Bence Jones Proteins, breast cancer markers including HER-2 and BRCA, SAA etc
- Paraneoplastic phenomena
- Endocrine effects of cancer - ectopic hormones, multiple endocrine neoplasia
- Prostatic cancer and PSA- including the role of free versus total PSA, age and race related reference ranges, new sensitive assays, standardisation, role of prostate volume and biopsy
- Tumour lysis syndrome-biochemistry related to high turn-over tumours and tumour breakdown

9.3.48 Toxicology, drugs and drug monitoring:

- Understanding of pharmacokinetic and pharmacodynamic concepts such as bioavailability, volume of distribution, drug half-life, steady state, first and zero order kinetics, clearance
- The effects of pH, protein binding and drug metabolism on drug levels
- Awareness of different pathways of drug elimination (including the CYP-450 and p-glycoprotein pathways) and drug solubility on drug levels
- The requirements to institute TDM and examples
- Pharmacogenetics-definition, examples of use such as measurement of Thiopurine methyltransferase (TPMT) activity and the investigation of a patient with Scoline apnoea
- Drug dose adjustment in patients with renal failure, low albumin levels and in children and geriatrics.
- Dibucaine and fluoride number to determine cholinesterase activity

9.3.49 Monitoring of drug therapy –toxicity versus therapeutic range

- Digoxin - Pharmacokinetics, timing of sample collection, drug interactions, factors affecting sensitivity, analytical methods and interferences and drug interactions
- Lithium - pharmacokinetics, toxicity, monitoring of therapy, measurement methods
- Anticonvulsants eg phenytoin and valproate- pharmacokinetics, toxicity, monitoring of therapy, measurement methods
- Theophylline and caffeine
- Methotrexate
- Antibiotics-Gentamycin, tobramycin Vancomycin
- Immunosuppressants
 - Biochemistry and mechanism of action of Cyclosporine, Sirolimus, Tacrolimus and Mycophenolic acid
 - Rational for measurement of the various immunosuppressants
 - Side effects of the drugs and the tests needed to monitor these eg U&E for cyclosporin
 - Varying ranges depending of relation to time and type of transplant
 - Methods of analysis
 - Cyclosporine: C2 versus C0 monitoring, measurement of parent versus daughter compounds and interferences and drug interactions

9.3.50 Pharmacokinetics and dosage prediction

- Zero and first order kinetics
- Solubility and distribution of drugs
- Half life and its calculation
- ED (effective dose)
- The methods for the assessment of renal function for drug dosage adjustments

9.3.51 Drug of abuse detection and monitoring

- Discuss the rules and regulations associated with workplace drugs of abuse programmes
- Chain of custody
- Contrast salivary versus urine testing for the detection of drugs of abuse
- Methods used for measurement including point of care and dry-chemistry to confirmatory tests performed on HPLC-MSMS and GC-MS
- Adulterated samples- laboratory tests to confirm or refute this
- Morphine derivatives
- Cannabis
- Amphetamines methods of detection and factors that influence measurement
- Metabolic effects of ethanol and methanol

9.3.52 Poisoning with:

- Lead
- Mercury
- Aluminium
- Iron
- Thallium

- Organophosphate.../

- Organophosphate compounds and cholinesterase measurement
- Carbon monoxide poisoning and the measurement of carboxyhaemoglobin
- Paracetamol - pathophysiology of toxicity and indications and mechanism of action of anti-dote N acetyl-cysteine
- Salicylates - clinical presentation and biochemical mechanism of toxicity
- Tri-cyclic antidepressants - clinical presentation and methods of analyses
- Methanol and ethylene glycol metabolism role of osmolar and anion gap in detection
- Barbiturates and benzodiazepines - clinical presentation, measurement of drugs and anti-dotes
- The laboratory approach to the poisoned patient
- The investigation of a patient known to have taken “muti”/herbal medicines
- The effect of herbal medicines on laboratory tests

9.3.53 **The laboratory investigation of the poisoned and /or unconscious patient:**

- Clinical presentation - Glasgow Coma Scale
- The performance of routine tests to assess metabolic status eg arterial blood gas, glucose, U&E and creat, LFT and CMP anion gap and osmolar gap and any other appropriate test eg thyroid functions
- If a drug overdose or poisoning is suspected the time of intake and the identification of the drugs or poisons is important. Analysis of drugs and stomach content may be required
- Forensic toxicology requirements such as chain of custody and appropriate collection procedures
- Laboratories should provide a 24/7 service. Methods for analysis include GC-MS, HPLC-MSMS, thin layer chromatography

9.3.54 **Occupational Health Monitoring:**

- Understanding of the laws governing occupational health monitoring and work place exposure and insight into the different industries
- Sampling requirements of patients and the environment and pre-analytical considerations eg timing of collection requirements for special tubes etc
- Awareness of the clinical presentation of exposure and toxicity
- Monitoring of solvent exposure eg hexane, toluene, perchlorethylene acetone, and styrene
- Monitoring of trace metal exposure eg lead, mercury, cadmium, chromium
- The use of Cholinesterase measurement in the monitoring of workers exposed to pesticides
- Methods needed to perform the analyses eg solvents by means of GC-MS and trace elements by means of ICP-MS and atomic absorption

9.3.55 **Metabolic response to insult and injury**

- Trauma
- Burns
- Water and electrolyte balance
- Sepsis and the laboratory assessment of sepsis
- Cytokines Proteins of inflammation
- SIRS
- Markers of traumatic brain injury

9.3.56 **Geriatric clinical chemistry**

- Theories regarding the physiology of aging
- The effect of a decline of metabolic function and organ integrity on laboratory results
- Drug metabolism in the elderly
- Reference ranges- challenges of assigning reference ranges in this age group

9.3.57 **Sport and the Chemical Pathology laboratory**

- Determination of performance enhancing drugs and hormones in sportsman and their consequences
- Tests to determine wellbeing
- Tests for the management of complications related to sporting activities

9.3.58 Wellness and anti aging tests

- Laboratory tests used to assess patient wellness
- Controversies relating to the performance of wellness testing including the use of tumour markers
- The effects of alternate medicines on laboratory tests
- The use of growth hormone, DHEAS amongst others, in adults to promote anti-aging

9.3.59 Insurance tests

- Test profile including serum cholesterol, cotinine, carbohydrate deficient transferrin levels etc
- Laws and regulations regarding testing

9.3.60 Transplants

- Biology of tissue transplant
- Understanding of the pathophysiology of acute and chronic transplant rejection
- The laboratory assessment of patients (and donors where appropriate) and criteria for kidney, liver and heart transplant, clinical service provision to transplant centres
- The role of the laboratory in monitoring patients in the acute and chronic post transplant phase
- The use of immune-suppressants in transplant

9.3.61 TPN

- Nutritional requirements of an intensive care unit patient
- Constituents of TPN
- Complications of TPN
- Laboratory monitoring of nutritional status of an ICU patient

9.3.62 Management Competencies

- Knowledge of laboratory organization including work flow, reporting systems, handling urgent, out-of-hours work and record maintenance
- Total quality management including quality assurance systems as indicated previously and managing and monitoring of key performance indicators namely turnaround times and error rates
- Using patient based quality control
- LEAN and Six sigma principles
- Understanding of the financial management of the laboratory including the reading of financial statements, preparation and operation of budgets, work load statistics, costing of tests, contracts and resource management etc
- Understanding the pros and cons of financial issues relating to analyser and test installation namely competitive tendering, capital purchase and reagent rental
- Understanding of the principles of stock control
- Knowledge of personnel management, job descriptions, performance appraisals, industrial relations and labour law
- Staff motivation and training including the regulations surrounding CPD
- Understanding of the principles of accreditation and the monitoring of this system
- Knowledge of the functioning of laboratory information systems and how these systems can be used to improve all laboratory processes including patient identification, quality control monitoring, result authorisation and reporting, management statistics, data storage etc Middleware its role and benefits. Requirements for the maintenance of data security and integrity
- Laboratory use of artificial intelligence and expert systems
- Autoverification, autovalidation and automated commenting-guidelines for use and the benefits of the processes
- Professional ethics- principles and practices, patient privacy and confidentiality
- Public relations with both the hospital staff and the public at large
- Legal requirements for laboratory operation including personal liability
- Laboratory design- including appropriate instrument and test menu selection, work flow analysis and laboratory automation, environment control etc
- Laboratory safety management including risk assessments, hazard management, radiation safety, waste disposal and accident and incident reporting
- Evidence based medicine and its application to the Clinical Chemistry laboratory
- Standards for reporting Diagnostic accuracy (STARD)
- Principles and practice of risk management
- Demand management and test utilization

9.4 Research Competencies**9.4.1 Aims**

- To enable the candidates to develop research skills by ensuring that they undertake analytically and clinically based research and/or service-orientated development projects or method evaluation projects under the supervision of an experienced research worker.

9.4.2 Objectives

- To ensure that the candidate can access and critically review relevant literature.
- To ensure that the candidate can formulate research questions and develop appropriate experimental design
- To ensure that the results are correctly analysed using appropriate statistical tools
- To ensure that the candidate develops research presentation skills and is capable of producing work of a publishable quality
- Presenting the results as a written report and/or as an oral presentation to the department, hospital or other scientific meeting

During the three-year training period a block of time will be spent on at least one project which addresses a relevant problem, and which would be suitable for publication in a peer-reviewed scientific journal. Evidence of this work will be required as a report written for publication. The work should be presented to the department, hospital or other scientific meeting

9.5 Communication skills**9.5.1 Aims**

- To ensure that the individual has the necessary skills to consult and communicate effectively and efficiently
- To present laboratory and research data in a scientific manner

9.5.2 Objectives

- To be able to resolve technical, scientific, clinical and management problems effectively
- To be able to work within a team
- To promote a high morale in the department
- Presentation of laboratory data at conferences, seminars, journal clubs, and clinical case meetings
- Effective patient communication
- Effective consultative skills

10.0 Recommended Study & Reference books**10.1 Clinical Chemistry**

These books marked with (*) are considered essential core reading (ideally the latest editions should be used)

Essential for new registrars (*)**Advanced (#)(reference/senior level)**

- Clinical Chemistry, 7th ed. W. Marshall, S. K. Bangert and M. Lapsley, Elsevier (2012)*
- Clinical Chemistry; Principles, Techniques and Correlations, 7th edition, Bishop, Fody & Schoeff; Wolters-Kluwer-Lippincott (2013)*
- Clinical Biochemistry, Metabolic and Clinical Aspects, 3rd ed, Marshall, Lapsley, Day and Ayling, Elsevier (2014)#
- Tietz Fundamentals of Clinical Chemistry and Molecular Diagnostics, 7th Edition, Burtis & Bruns. 7th ed. Saunders, (2015)*
- Tietz Textbook of Clinical Chemistry and Molecular Diagnostics, 5th ed, Burtis, Ashwood and Bruns, Saunders (2012) #
- The UCT Medical Student undergraduate notes(*) – Free on the following URL: [http://www.chemicalpathology.uct.ac.za/sites/default/files/image_tool/images/10/Chemical Pathology MBChB student lecture notes 2013.pdf](http://www.chemicalpathology.uct.ac.za/sites/default/files/image_tool/images/10/Chemical_Pathology_MBChB_student_lecture_notes_2013.pdf)
- Clinical Chemistry. Theory, Analysis and Correlation. Kaplan LA, Pesce AJ. 5th ed. Mosby, 2009*.

- Tietz Clinical Guide to Laboratory Tests. Tietz N(Ed). 4th ed. Saunders, 2006.
- Henry's Clinical Diagnosis and Management by Laboratory Methods. Henry JB. 21st ed. Saunders, 2006.
- Lecture Notes on Clinical Chemistry. Whitby LG, Percy-Robb IW, Smith AF. 4th ed. Blackwell, 1988.
- Biochemical Basis of Paediatric Disease. Soldin SJ, Rifai N, Hicks JMB, 3rd ed. American Association for Clinical Chemistry, 1998.
- Cases for Chemical Pathology. A Diagnostic Approach. Walmsley RN, Watkinson LR, Koay ESC. 4th ed. World Scientific, 1999.

10.2 Biochemistry

- Biochemistry: A case oriented approach. Montgomery R et al. 6 ed. Mosby, 1996
- Clinical laboratory Medicine: Clinical Application of Laboratory Data. Ravel R(Ed) 6th ed. Mosby, 1995
- Medical biochemistry at a glance, 3rd edition, Salway; Wiley (2012)

10.3 General

- Harrison's Principles of Internal Medicine. Wilson JD, et al., 18th ed. McGraw Hill, 2012.
- The Metabolic Basis of Inherited Disease. Scriver CR, Beaudet AL, Sly WS Valle D, 7th ed. McGraw Hill, 2000.
- Inborn Metabolic Diseases : Diagnosis and Treatment Fernandes, Saudubray & van den Berghe Springer Verlag Berlin Edition
- Current Medical Diagnosis and Treatment 2010. Stephen J. 49th ed. Lange, 2009.
- Williams Textbook of Endocrinology. Wilson JD, Foster DW. 10th ed. Saunders, 2002.
- Goodman and Gilman's The Pharmacologic Basis of Therapeutics. Laurence Brunton. 11th ed. McGraw Hill, 2005.
- Greenspan's Basic and Clinical Endocrinology. Greenspan FS, Forsham PH (Eds.), David Gardener 8th ed.
- Lange Series. Appleton and Lange, 2007.

10.4 Calculations books

- Calculations in Laboratory science by Allan Deacon Published by Ace Venture Publications 2009
- Statistics and Chemometrics for Analytical Chemistry by James N Miller and Jane C Miller. 6th edition Publisher: Pearson Prentice Hall Number ISBN-13: 978-0273730422
- Interactive Mathematics for Laboratory Medicine by T.S. Pillay; published by Apple Computer Corporation. ISBN 978-0-620-66537-7 (Apple version)
URL: <https://itunes.apple.com/us/book/interactive-mathematics-for/id1038925720?mt=13>
ePub3 version for Android and Windows ISBN 978-0-620-69120-8; published by Draft2Digital; available on Inktera.com

10.5 Practical books

- Practical Clinical Chemistry: core concepts- a training manual by T.S. Pillay; published by Apple Computer Corporation. ISBN 978-0-620-63326-0 (Apple version); URL: <https://itunes.apple.com/us/book/practical-clinical-chemistry/id951030209?mt=13>

10.6 Journals

- American Journal of Clinical Pathology
- Annals of Clinical Biochemistry
- Annals of Internal Medicine
- British Medical Journal
- Clinica Chimica Acta
- Clinical Chemistry
- Clinical Biochemistry Reviews
- Clinics in Endocrinology and Metabolism

- Clinics in Laboratory Medicine
- Critical Reviews in Clinical laboratory Sciences
- Current opinion in Lipidology
- Current opinion in Diabetes and Metabolism
- Endocrinology. Endocrine reviews
- Journal of Bone and Mineral Research
- Journal of Clinical Chemistry and Clinical Biochemistry
- Journal of Clinical Endocrinology and Metabolism
- Journal of Clinical and Laboratory Medicine
- Journal of Clinical Pathology
- Journal of Lipid Research
- Kidney International
- Lancet
- New England Journal of Medicine
- Paediatric Research
- Therapeutic Drug Monitoring
- Scandinavian Journal of Clinical and Laboratory Investigation Science

11.0 References

- Royal College of Pathologists UK – Core Guidelines Clinical Biochemist Grade A training record: section six
- Royal College of Pathologists Australasia (RCPA) trainee handbook.
- Post Graduate Training Program in Clinical Biochemistry – Canadian Society of Clinical Chemists
- Curriculum of the Department of Chemical Pathology UCT
- Curriculum of the Department of Chemical Pathology Stellenbosch University