PRACTICAL 1 KIDNEY:
PHYSICAL AND CHEMICAL PROPERTIES OF THE URINE: THE ROUTINE URINALYSIS

- Physical properties
- Chemical properties
- Microscopic examination
- Clinical importance
  - Information about
    - State of kidneys and urinary tract
    - Major metabolic functions
  - Monitor treatment and progress of disease

Kidney function
- Removal of metabolic waste products and toxic substances
- Regulation of volume and composition of body fluids by reabsorption and secretion
- Retention of nutrients
- Maintenance of water and electrolyte balance, acid-base balance;
- Maintenance blood pressure and erythropoiesis, producing substances important to the metabolism of other body tissues
- Hormone synthesis

Filtration
- Kidneys receive 22% of CO or ~ 1100 ml blood/min
- Glomerular filtration [glomerular capillaries (high-hydrostatic press ~ 60mmHg), filtration barrier, hydrostatic press. (~18 mmHg) and colloid osmotic press. (~0 ) in Bowman’s capsule…]
  - Filtered: salts and organic molecules with low-MW in similar concentrations with the plasma ones
  - Not filtered: proteins (responsible of a colloid osmotic press of ~32 mmHg !!), cells, fatty acids and calcium bound to plasma proteins
  - Results in ultrafiltrate of plasma (protein-free, cell-free plasma)
- GFR = 120-125 ml of filtrate/minute or 180 l/day, filtration fraction ~ 20% of renal plasma flow

Reabsorption
- In the proximal tubule certain elements from the glomerular filtrate are reabsorbed into the bloodstream [peritubular capillaries (low hydrostatic press ~ 13 mmHg)]
  - Ions / salts (partial reabsorbed)
  - Glucose, Amino acids (complete reabsorbtion)

Concentration
- Water is removed by osmosis in the loop of Henle
- Final concentration of urine is controlled by hormones in the distal tubule

Secretion
- Substances are removed from the blood also by secretion into the tubules
  - Maintain salt and water balance
  - Elimination of waste products
  - Regulation of acid/base balance

Composition of urine
- 96% water and 4% dissolved substances
- Normal organic substances
  - Urea
  - Uric acid
  - Creatinine
- Normal inorganic substances
  - Sodium -ammonium
  - Potassium

Urine formation
- In general, urine can be considered a fluid composed of the waste materials of the blood
- Urine is formed continuously in the kidney and excreted from the body by the urinary system

Physical properties
- Color
- Transparency
- Specific gravity
- Volume
- Odor
- Foam

**Chemical tests**
- Screening, semi-quantitative tests usually with reagent strips
- Ph
- Protein
- Glucose
- Ketones
- Bilirubin
- Blood
- Urobilinogen

**Microscopic examination**
- Helpful to diagnose kidney and urinary tract disease
- Red blood cells
- White blood cells
- Epithelial cells
- Casts
- Bacteria
- Crystals

**Collection of urine specimens**
- Random specimen
- Freely voided specimen collected anytime during the day
- First morning specimen clean catch - midstream
- From catheter

**Physical properties of urine**

**Volume**
- Not usually measured in routine urinalysis
  - Diuresis: in normal adults volume is 1,000 to 1,800 ml; can increase in volume, even temporary
  - Polyuria - over 2,000 ml/24 hr.
  - Oliguria- less that 500 ml/24 hr.
  - Anuria- complete absence of urine formation
  - Nocturia - excretion of urine at night

**Color**
- Normal color of urine is yellow caused by a pigment
  - Urochrome
  - Urobilin
- Intensity of color varies with the concentration
  - Other colors may be due to variations of diet, medication or disease
- Dark yellow/amber
  - Very concentrated and low volume
  - Fever / dehydration
- Brown
  - Bilirubin
    - Yellow foam
    - May become green
- Orange
  - May contain urobilin
    - Does not show in fresh specimens
    - No foam
- Bright orange:
  - Certain azo dyes
- Clear red
  - Hemoglobinuria
• Cloudy red
  o Hematuria
• Dark red brown
  o Myoglobin

**Transparency of urine**
• Fresh urine is usually clear - cloudiness may be caused by several factors
  o Amorphous urate or phosphate crystals
  o Mucous threads
  o Presence of white blood cells
  o Red blood cells
    ▪ Cells are confirmed by microscopic examination
• Clear
  o No visible particulate matter
• Hazy
  Some visible particulate matter: newsprint is not distorted
• Cloudy
  o Newsprint can be seen, but is distorted
• Turbid
  o Newsprint cannot be seen through specimen

**Specific gravity**
• Provides information about the kidneys ability to concentrate the glomerular filtrate
• Normal specific gravity ranges from 1.005 - 1.030
  o First morning urine will be the most concentrated of the day
  o Dehydration can cause urine to be highly concentrated

**Measuring specific gravity** - a measure of ionic concentration

**Urinometer - traditional method**
• Uses a glass float weighted with mercury and a stem with calibrations to measure the buoyancy
  o Relatively time consuming; Required large volume of urine
• The specific gravity of a solution is dependent on temperature

**The refractometer**
• A measure of dissolved particles in solution:
  o Closely correlated with specific gravity
  o Requires only a drop of urine
• Actually measures refractive index which agreed with specific gravity up to 1.035
  o Distilled water has a refractive index of 1.000

**Chemical properties of urine**

**pH**
• The lungs and the kidneys are the major regulators of the acid-base contents of the body
• There is no normal- urine pH can range from 4.5 to 8.0
  o Acid-base content of the blood
  o Diet
  o Renal function

**Ph - clinical significance**
• Systemic acid-base disorders
• Determines crystal formation
• Reagent strips use a double indicator system of methyl red and bromthymol blue

**Protein**
• Normal urine contains very little protein <100-150 mg/day
• Albumin is the major serum protein found in normal urine
  o Tamm-horsfall protein is produced by the tubules is not measured
• Elevation of protein is often the first indication of renal disease

**Proteinuria: Clinical significance**
• Does not always signify renal disease but always required additional tests to rule out
• Pathological causes of proteinuria
  o Glomerular membrane damage
  o Tubular reabsorption problem
  o Increased serum levels of low-molecular weight protein
  o Lower urinary tract infections

Glucose
• The most frequent test performed on urine
  o For diabetes mellitus
• Normal urine contains only minute amounts of glucose
  o A normal person may have glycosuria after a meal high in glucose
• Elevated blood glucose may exceed the "renal threshold" ~180 mg glucose/dl of blood and allow glucose to be detected in the urine

Oxidation reduction tests for glucose
• Less sensitive than reagent strip; requires Fehling reagent (blue) which will turn brownish-red in contact with glucose
• Non-specific tests measures all reducing substances

Ketones
• Ketones represent three intermediate products of fat metabolism
  o Acetone
  o Acetoacetic acid
  o Beta-hydroxybutyric acid
• Normally fat is oxidized to CO2 and H2O
• Sodium nitroprusside reaction measures ketones
  o Acetacetic acid reacts with indicator to produce a purple color

Increased fat metabolism
• Diabetes mellitus
• Severe vomiting
• Starvation diets
  o Accumulation of ketones in the blood causes acidosis
• Sodium nitroprusside reaction measures ketones
  o Acetacetic acid reacts with indicator to produce a purple color
• Test does not measure beta-hydroxybutyric acid and is only slightly sensitive to acetone

Dilution - Concentration test
• Stimulatory test on ADH production / kidney function
• Test measures the ability of the kidneys to conserve or excrete water appropriately.
• Changes - diabetes insipidus = inability of the kidneys to conserve water, which leads to frequent urination and pronounced thirst.
  o central (hypothalamic) = a lack of ADH
  o peripheral (nephrogenic) = a defect of the kidneys
• The specific gravity of urine is measured:
  o before and after water loading (urine should become dilute),
  o during water deprivation (urine should become concentrated),
  o for water deprivation and administration of ADH/vasopressin
Urine sediment

- RBC (Red Blood Cells)
- WBC (White Blood Cells)
- Bacteria
- Squamous cells
- RBC cast
- WBC cast
- Granular casts
- Waxy casts