The rate of fluid filtration, GFR, can be measured with the use of inulin. The rate at which inulin is filtered, \( GFR \times P_{in} \), equals the rate it is excreted, \( U_{in} \times V \).

\[
GFR \times P_{in} = U_{in} \times V
\]

\[
GFR = \frac{U_{in} \times V}{P_{in}}
\]

Units are volume / time: ml / min, L / day.
The rate of reabsorption of a solute, $T_s$, is the difference between the rate of its filtration, $GFR \times P_s$, and the rate of its excretion, $U_s \times V$. 

$$T_s = (GFR \times P_s) - (U_s \times V)$$

Units are mass / time: mg / min, mMoles / min.
The rate of secretion of a solute, $T_s$, is the difference between the rate of excretion, $U_s \times V$, and the rate of filtration, $GFR \times P_s$.

$$T_s = (U_s \times V) - (GFR \times P_s)$$

Units are mass / time: mg / min, mMoles / min.
CLEARANCE is a term used to describe the rate of removal or ‘clearing’ of a substance from the blood. It is often used to measure the efficiency of the kidney in removing a substance from the blood.

DEFINITION: Volume of plasma cleared of a substance per unit time.

Clearance = excretion rate / plasma concentration.

\[ C_s = \frac{U_s V}{P_s} \]

UNITS: (µmoles/min) / (µmoles/ml) = ml/min
Clearance rates of substances may or may not vary with changes in their plasma concentration.

A. The clearance of a substance that is neither reabsorbed or secreted does not change when the plasma concentration changes.

B. The clearance of a substance that is reabsorbed tends to increase when the plasma concentration rises.

C. The clearance of a substance that is secreted tends to fall when the plasma concentration rises.
A. All filtered glucose is reabsorbed at plasma concentrations below 250 mg/dl. The reabsorptive mechanism becomes saturated at plasma concentrations above 350 mg/dl. The maximum transport rate ($T_m^g$) is about 375 mg/min. Glucose begins to appear in the urine at about 250 mg/min.

B. The clearance of glucose ($C_g$) is 0 when the plasma concentration is below 250 mg/dl because no glucose is excreted. Above that concentration $C_g$ rises and begins to approach the clearance of inulin ($C_{in}$).
USE OF CREATININE TO MEASURE GFR

Major Advantage: An endogenous substance present in body fluids at concentrations that normally vary little. Thus does not require an IV infusion as inulin does.

Most of the excreted creatinine has been filtered and none is reabsorbed.

Major Disadvantage: Creatinine is secreted by the proximal tubule to a slight extent. Thus the creatinine clearance may exceed the GFR.

When glomerular function is reduced, the fraction of the creatinine clearance due to secretion increases, raising the error in GFR determination.

Certain drugs affect the secretion of creatinine.

Problems in quantitative collection of all urine produced during a clearance period complicate determination of clearance.
UTILITY OF PLASMA CREATININE MEASUREMENT

P_cr mg%

1/P_cr

PERCENT OF NORMAL GFR
MDRD Formula:
Measurements needed: $S_{cr}$, BUN, Alb.

$$\text{GFR (ml/min/1.73 m}^2\text{)} = 170 \times S_{cr}^{-0.999} \times \text{Age}^{-0.176} \times \text{BUN}^{-0.17} \times \text{Alb}^{0.318}$$
Multiply by 0.762 if female; 1.18 if African-American

If BUN and Alb are not available:

$$\text{GFR (ml/min)} = 186 \times S_{cr}^{-1.154} \times \text{Age}^{-0.203}$$
Multiply by 0.742 if female; 1.21 if African-American

Cockroft-Gault formula:
Measurements needed: $S_{cr}$

$$C_{cr} \text{ (ml/min)} = ((140-\text{Age}) \times \text{kg bw})/(72 \times S_{cr} \text{(mg/dl)})$$
FRACTIONAL EXCRETION OF WATER

\[
\frac{V}{GFR} = \frac{V}{U_{cr}V/P_{cr}} = \frac{P_{cr}}{U_{cr}}
\]
FRACTIONAL EXCRETION OF SOLUTE

\[
FE_s = \frac{excreted \ solute}{filtered \ solute} = \frac{U_s \times V}{GFR \times P_s} = \frac{U_s}{U_{cr}} / \frac{P_s}{P_{cr}} \times 100 = \% 
\]