Biochemistry of Saliva, Teeth, and Dental Caries

Saliva

♦Biological fluid, which bathes the oral cavity.

♦Complex fluid produced by a number of specialized glands which discharge into the oral cavity.

♦Contains electrolytes and proteins.

- The same electrolytes (minerals in the blood and other body fluids) that carry an electric charge.

♦The total volume of saliva produced each day in adults is 500 to 1500 ml.

Function of saliva

- Antibacterial and antifungal action
- Buffering
- Digestion
- Mineralization
- Lubrication
- Many salivary components do multiple functions. For example, amylase in addition to being an enzyme also inhibits precipitation of calcium salts.

Source and characteristics of saliva

The parotid glands	• produce serous secretions only, devoid of mucin
The submandibular and sublingual glands	• secrete both serous and mucinous secretions
The viscosity of the submandibular saliva	• usually decreases with increasing flow rate
Salivary secretion	• stimulated by smell and taste.

Composition of saliva

General

- Volume 500-1500 ml /day
- Rate of flow 0.1--0.25 ml/min
- pH 5.6-7.2 (mean 6.5)
- Water content 97-99.5%

Proteins

- Total protein 1-6 g/ L
- Mucin 2.7 g / L
- Statherins
- Proline rich proteins
- Hystatins

Enzymes

- α-amylase
- Cholinesterase
- Lipase
- cretin-kinase aspartate-tramsaminase
- Lactat dehydrogenase 113-609 U/L
- Adenosine deaminase
- Lysozyme
- carbonic anhydrase

Metabolites

- Glucose 0,5-1 mmol/L
- Total lipid 20 mg/dl
- Cholesterol 7.5 mg/dl (0.19 mmol/L)
- Urea
- Uric acid
- Creatinine
- lactate

Electrolites

- Potassium 10-40 mMol/L
- Sodium 2-50 mMol/L
- Calcium 1-2.5 mMol/L
- Magnesium 0.2--0.6 mMol/L
- Phosphate 2-22 mMol/L
- Chloride 5-50 mMol/L

Hormones

- Cortisol 3-40 nmol/L*
- Dehydroepiandrosterone 1.5±0.3 nmol/L
- Free testosterone 18.71±5.01 pg/mL
- Insulin

- *depends on method

Organic compounds

Major carbohydrate in saliva

- glucose (0,5-1 mmol/L)

Hormones, immunoglobulins and enzymes

- may be detected in saliva in trace amounts

The total protein concentration in saliva

- less than 1% of that in plasma

Important proteins of saliva

- mucin, statherins, histatins, proline rich proteins (PRPs), lactoferrin and immunoglobulin A (IgA) and different enzymes: carbonic anhydrase, lingual lipase, amylase, peroxidase

Salivary Mucins

Characteristics

- major proteins of the saliva
- exist in two forms
  - MG1 and MG2
- Glycoproteins with negatively charged groups
  - sialic acid and sulfate
- hydrophilic and trap water resulting in high elasticity
- The oligosaccharide residues bind to bacterial proteins
  - preventing them from adhering to soft tissue and enamel

Function

- **Tissue coating**
  - Protective coating about hard and soft tissues
  - Primary role in formation of acquired pellicle
  - Concentrates antimicrobial molecules at mucosal interface
- **Lubrication**
  - Align themselves with direction of flow increases lubricating qualities

Salivary enzymes

The main enzymes **amylase, lingual lipase**	• digestion
Carbonic anhydrase	• buffering action of saliva
Peroxidases	• bactericidal function
Lysozyme	• antimicrobial action • bactericidal effect: by breaking down the muramic acid present in bacterial cell walls
Enzymes and other proteins	• synthesized by the **acinar cells**.

Amylase

- The major salivary enzyme
- Secretion: The parotid gland
- It cleaves the alpha-1,4-glycosidic bonds of starch
- The products are small quantities of maltose (disaccharide) and smaller sized polysaccharides.
- The optimum pH is 6.
- its action is short lived as the food passes into stomach (lower pH inactivates the enzyme)
- When there is any obstruction to the salivary ducts or inflammation of the glands (as in mumps), the salivary amylase passes into the blood and elevates the concentration and activity of serum amylase.
- weak antibacterial properties
- buffering property

Other proteins

Immunoglobulin A (IgA)

- **secretory** antibodies (present in body secretions)
- effective against **cariogenic bacteria**
- IgA concentrations-low in some persons with dental caries

Lactoferrin

- chelates the iron.

Histidine rich proteins

- antifungal activity
- reduces the bacterial attacks
- reduce precipitation of calcium phosphate
- help in the formation of the enamel pellicle
- Slows down the loss of calcium and phosphate ions from the teeth

Statherins

- keep the supersaturated calcium phosphate in the ductal saliva from crystallizing
- The supersaturated calcium phosphate is necessary for the maintenance of enamel integrity.
- bind calcium and prevent precipitation of calcium phosphate (probability of formation of dental calculus is reduced).
- help in lubrication.

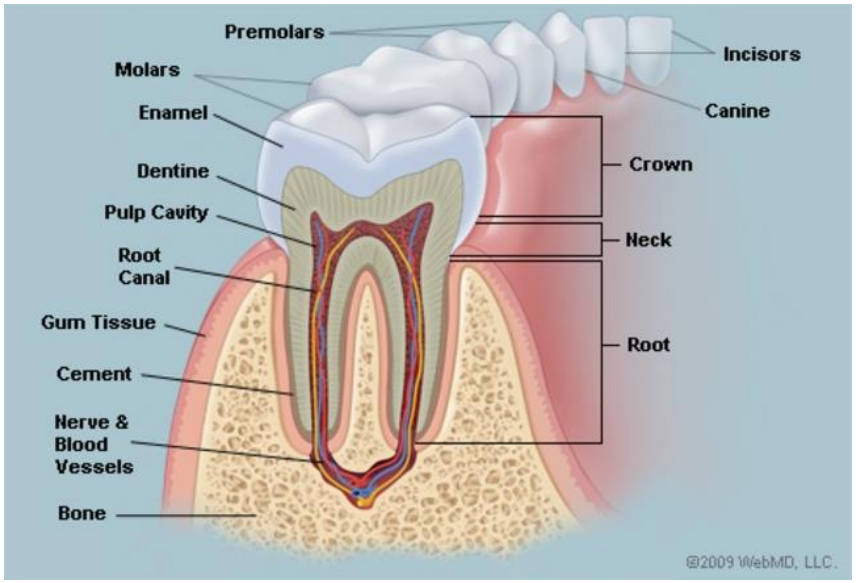
Inorganic Components

Saliva contains the most common electrolytes of the body fluids: **sodium, potassium, chloride and hydrogencarbonate.**

Formation of the teeth

Close association of inorganic (mineral) crystal material, and organic fibrous (polymer) structures.

Both components playing a structural role in the tooth.



https://www.webmd.com/oral-health/picture-of-the-teeth#1

Inorganic composition of the teeth

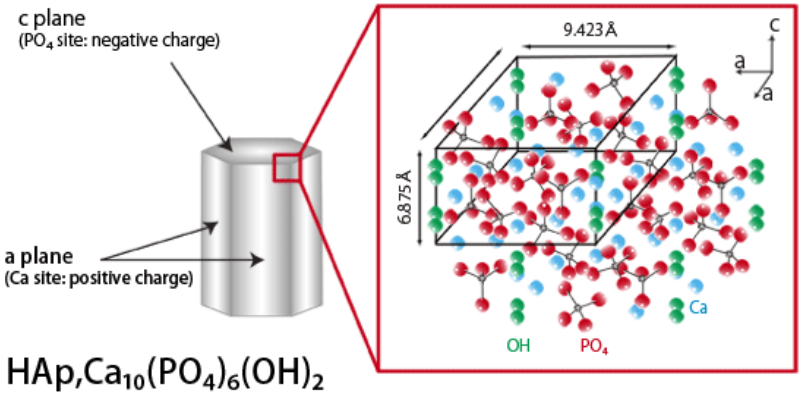
Hydroxyapatite (97 % of enamel and 70 % of dentin)

- the major form of calcium in all the tooth tissues

crystalline forms of calcium phosphate

Amorphous (**noncrystalline**) calcium phosphate

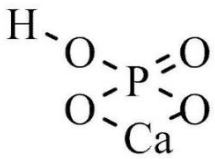
- in the dentin.



$HAp, Ca_{10}(PO_4)_6(OH)_2$

https://sofsera.co.jp/english/tech1_e.html

The phosphate ions constitute the major component of the ions present in the crystal arranged in **octahedral channels** running through the crystal structure



- Two-thirds of these channels are occupied by **calcium ions**.
- One-third of the channels are occupied by **negative fluoride ions (fluoroapatite)**

TRACE ELEMENTS In human enamel,

- **iron, zinc, copper, and manganese**

Organic Components

Collagen

- the major protein component of calcifying tissues like bone, dentin and cementum.
- Each polypeptide chain about 1000 amino acid residues.

The structural proteins and apatite of teeth need to be synthesized in an integrated way.

In teeth the collagen fibrils are suited to the roles of supporting three-dimensional stress, and of orienting and supporting apatite crystals.

Other Proteins in Teeth

- the extracellular matrix also contains
  - glycoproteins (GP)
  - glycosaminoglycans (GAG)
- These proteins are associated with the dentin and basal plate.

Proteins of Dentin

Specific for teeth and bone

Three major proteins specific for dentin

Collagen

non-collagen proteins

Dentin phosphoryn

Dentin matrix protein

Dentin sialoprotein

forms the lattice for mineralization

acidic glycoproteins and proteoglycans

control initiation and growth of crystals.

These proteins play an important role in control of mineralization.

Proteins of Enamel

Amelogenin

a low molecular weight extracellular matrix protein.

about 90% of all enamel protein.

hydrophobic residues on the outside.

Function of amelogenin

The 27 amino acid functions as a calcium channel.

Phosphorylation of a serine residue of the protein opens the calcium channel

calcium ions zoom through and funneled to the mineralization front.

It also influences the development of cementum.

Other proteins of enamel

Ameloblastin
Enamelin
Tuftelin

Mineralization

- **a process by which inorganic calcium and phosphate are deposited on the organic matrix.**
- **Osteoblasts** synthesize and secrete organic matrix, which is then mineralized.
- **Osteoclasts** are Involved in bone resorption.
- **Alkaline phosphatase**
  - the key enzyme in the process of mineralization
  - liberates phosphate from substrates
  - Ionic concentration is increased to supersaturation level
    - leading to deposition of apatite

DENTAL CARIES

DENTAL CARIES (dental cavities or tooth decay)

Caries (*Latin*)= "decay".

- **local destruction of tooth tissues with demineralization.**
- In the pits and fissures of premolar and molar teeth, bacterial fermentation of residual food leads to acid production.

Bacteria
Streptococcus mutans

- Proliferates because of:
  - decrease in saliva flow
  - the pH of the plaque drops to ≤5
- forms dextran and causes a sticky plaque, trapping bacteria, calcium and phosphate ions

THE CAUSES OF DENTAL CARIES

Sucrose

- low-molecular-weight disaccharide
- rapidly metabolized by the plaque flora
- fermentation produces lactic acid
- drop in the pH to ≤5 at the Point of interface between plaque and enamel

Other

- poor oral hygiene
- chewing of tobacco
- exposure to lead, cadmium (metals that can replace calcium
- Iodine is found to be able to penetrate enamel, dental pulp and periodontal tissues
- frequent eating (lower pH)

Prevention of Caries

- oral hygiene
- regular dental examination and cleaning 6 months
- Consummation of high molecular weight starch
- fluoride (2-4 μg daily)
  - a. Effect on hard tissues to modulate mineralization, demineralization and re-mineralization.
  - b. Effect of cariogenic bacteria by altering their metabolism.
  - c. Effect on soft tissues to modify the development of teeth
- sugar free salivary stimulants

Fluorosis-state of art

>2 mg/l

- chronic intestinal upset, gastroenteritis, loss of appetite and loss of weight

>5 mg/L

- mottling of enamel, stratification and discoloration of teeth

>20 mg/L

- toxic, leading to alternate areas of osteoporosis and osteosclerosis, with brittle bones

Ingested fluoride accumulates in bones

Fluorosis

- blood concentration of fluoride up to **50** μg **/100 ml** (normal up to 4 μg /100 ml).

joint defects

- increased breakdown of bone matrix
- increased excretion of hydroxyproline in urine is enhanced.

Fluorinated toothpaste?

Constantly follow the recommendations of the profession in terms of recommending the use of fluoride in prevention, consumption and treatment

- de Almeida PDV, Grégio AMT, Machado MÂN, de Lima AAS, Azevedo LR. Saliva Composition and Functions: A Comprehensive Review. J Contemp Dent Pract 2008 March; (9)3:072-080.