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SPECIAL ARTICLE

The history and science of chocolate

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Abstract

This article gives an account of the origins, evolution and properties of chocolate. Chocolate is processed from the pod or cabosside of the cacao plant, grown in the tropical belt. The origins of chocolate are traced back to the Maya people who were probably the first to cultivate the cacao plant. The early chocolate drink, considered a "drink of the Gods" was mixed with cinnamon and pepper, tasting bitter and strong, and was most appreciated for its invigorating and stimulating effects than for its taste. Imported from the Americas, the softened version soon spread in Europe. From the 1800s to the 20th Century, it evolved from a drink to its current pleasurable varieties (such as fondant, Gianduja, milky and white chocolate), gaining much momentum in industry and also made great impact as a romantic item and art form. Important components in chocolate are flavonoids (antioxidants), cocoa butter, caffeine, theobromine and phenylethylamine, whereas the presence of psychoactive substances account for its pleasurable effects. Caffeine, theophylline and theobromine constitutes the methylxanthines, known to enhance the action of cAMP, which plays an important role in the transmission of intracellular signals. Chocolate is noted to have anti-inflammatory, neuroprotective and cardioprotective effects, and improves the bioavailability of nitric oxide, which action improves the pressure, platelet function and fluidity of blood.

Key words: chocolate, antioxidant, theobromine, methylxanthines, nitric oxide, endothelium

Almost everyone, especially children, love chocolate. But do we know what it really is? In addition to its tasty flavor, do we know its origins, evolution and properties? In this paper, I will try to share some useful information on what it is.

From tree to chocolate

Cacao is grown in a tropical belt straddling the equator - between 10 and 20 degrees north to south, in the area called the "cocoa belt". The tree can be very tall - up to 12 meters. It starts bearing after about 5 years, but takes 10 years to reach maximum yield.

Its fruit, called a pod or cabosside, can take a color ranging from brown/yellow to purple, and contains 20 to 40 seeds or cocoa beans. Each plant produces 20 to 50 cabossides a year, with about 10 cabossides needed to produce a kilogram of cocoa (Fig. 1a and b).

The taste of the cocoa bean depends not only on the variety of plant, but also on the soil, environmental temperature and

FIG. 1. (a) Cocoa tree (b) Cabossides

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FIG. 2. Montezuma drinking chocolate

the amount of sunlight and rain received. After a process of fermentation and drying in the sun, the beans are packed for local consumption or manufacture into cocoa and chocolate. In processing into cocoa or chocolate, the seeds are first roasted to the characteristic color of cocoa. Finally, the shell is removed from the roasted seeds which are then ground into a fine grain or powder. Hotter roasting will produce a cocoa liquor and subsequently, with additional heat and pressure, cocoa butter and cocoa powder. To produce a very silky texture, a long process of mixing and heating is finally carried out.

The origins: Maya and Aztecs

The origins of chocolate are very old, usually traced back to the Maya people, who were probably the first to cultivate the cacao plant, in 400 AD. The plant we know today is the result of crossing and selection that had already started 35,000 years ago. The consumption of cocoa then was different from what it is today: the dried cocoa beans were ground and dissolved in water, with cinnamon and pepper added to enhance the flavor which was decidedly bitter and strong. The drink took the name of xocolatl. It can be inferred that the drink was most appreciated for its invigorating and stimulating effects than for its taste, effects well known to the ancients.

When, in 1200 AD, the Aztec domination of the Maya began, the drink was particularly appreciated by Emperor Montezuma who is said to be so enamoured of it that he consumed dozens of cups a day (Fig. 2). Cocoa beans were considered so valuable that they were used as currency and kept in safes along with gold and precious stones.

According to ancient records, the Aztecs believed that the god Quetzalcoatl came to Earth on rays of light from the Star of the Morning, bringing from heaven the cocoa tree for mankind. They learned from Quetzalcoatl to toast and grind the seeds to obtain a nutritious paste, soluble in water. They added spices to produce the drink "tsocolatl", or "bitter water", believed to confer them wisdom and universal knowledge.

Drink of the Gods

According to mythological origins (winners always write history the way they want it), cocoa originated from the sacrifice of an Aztec princess, who preferred death by the enemy to revealing the riches of her kingdom. From her blood sprung the delicate cacao plant, with mystical meanings and aphrodisiac properties, to be given as a drink to priests and warriors.

Today, the cocoa plant is grown in several countries, mainly, Ivory Coast, Ghana, Indonesia, Nigeria, Brazil, Cameroon, Ecuador, Dominican Republic and Papua New Guinea. Other countries cultivating it are Madagascar, Malaysia, Mexico, some Caribbean islands, such as Granada, and Cuba, and some Pacific islands, like Samoa.

In 1502, the first meeting of Western civilization with cocoa occurred: Christopher Columbus landed on the island of Guanaja, Honduras, and received the gift of a cup of chocolate (Fig. 3). Columbus at first, then Cortes,

FIG. 3. Columbus and Montezuma

discovered in the Americas the cocoa plant, but only Cortes brought the seeds to Europe. From this moment onwards, due to frequent trade with the American colonies of the Spanish, chocolate began to be introduced in the old continent as a beverage.

At first the Spaniards followed the recipe of the Aztecs, with further addition of chilli and hot spices. Then, with the addition of sugar, cinnamon and vanilla, the cocoa taste became sweet and soft.

Table 1 summarises the early chronology of chocolate drinks.

Imported from the Americas, in the European courts, the softened version (compared to the original strong and spicy beverage) soon spread, initially as a medicine and stimulant.

Starting from 1660, the drinking of hot sweet chocolate spreaded across Europe: Belgium, Germany and Switzerland, and also Austria and Italy. Venetian and Florentine masters gave life to the art of chocolate preparation. In England, there were Chocolate Houses for the wealthier classes.

In 1662, Cardinal Brancaccio pronounced that drinking hot chocolate did not break the fasting period, spurring spread of the drink in monasteries and the European courts.

In 1753, the Swedish naturalist, Carl von Linné, named the cocoa tree *Theobroma cacao*: Food of the Gods.

From 1750 to 1790, the Arcadia devoted attention to chocolate with poems, such as *Metastasio*, *Baruffaldi* and *Parini*, but the real consecration of the drink was only after the middle of the eighteenth century, in France becoming fashionable among the European aristocracy.

The chocolate industry

Table 2 summarises the evolution of the chocolate industry. In this, the conching process deserves special mention. Conching is mixing cocoa with various ingredients, such as milk, vanilla and extra cocoa butter for a very long time (12 to 48 hours) at a controlled temperature to maintain the liquid texture. After this, the chocolate is kept melted in tanks at 45 - 50°C (Fig. 4a and b).

The art in chocolate

The theme of chocolate has been addressed several times in the seventh art, cinema. The films include: *Chocolat*, *Like water for Chocolate*, *Hot Chocolate*, *Chocolate Factory*, *Lessons in Chocolate* and *Bianca* (Fig. 5).

But art is also the transformation of a material (chocolate) to particular aesthetic forms (Fig. 6). The main pictorial representation is by Jean Étienne Liotard, the Nice chocolate maker (Fig. 7). Giancarlo Bononi and Michel Mandurino combined the theme of Caravaggio with that of Cioccoshow in a photo exhibition (Fig. 8).

Varieties of chocolate

Fondant. This is the most expensive chocolate. With the intense and persistent aroma of cocoa

TABLE 1: Early chronology of the chocolate drink

Liquid chocolate, bitter and spicy	
300-900 A.D	Mayans melted cocoa into a bitter drink, probably making and consuming it warm with corn
1375-1521	Aztecs melted cocoa into a bitter drink, probably drunk cold with spices
Liquid chocolate, bitter and cold	
1565	Published in Venice “Historia del Mondo Nuovo” in which Italian traveler, Girolamo Benzoni, stated that bitter cacaute was “food more for pigs than humans”.
Liquid chocolate, sweet and hot	
1585	In Oaxaca, Mexico, nuns in a convent mixed sugar with cocoa and consumed it hot and sweet, as a drink.

Table 2. Evolution of the chocolate industry

1815	Conread Van Houten of Amsterdam island made cocoa butter from cocoa mass
1832	Franz Sacher in Vienna invented his famous cake
1847	Fry produced the first solid chocolate bar with cocoa beans, sugar and cocoa butter
1865	Production of pasta gianduja in Turin, brainchild of Michael Prochet and Isidore Caffarel
1875	Milk chocolate made by Swiss Daniel Peter with condensed milk powder from Nestle Henry
1875	Fry created a chocolate bar flavoured with mint
1879	Rudolph Lindt in Switzerland produced the first dark chocolate, by "conching"
1900	Milk chocolate becomes a food for everyone: claimed by Swiss chocolate factories, Lindt & Sprüngli, Tobler Suchard
1905	Cadbury sells 'Dairy Milk' chocolate
1907	Hershey in America invented 'Kisses '
1914	In France appeared Banania: cocoa powder, sugar and chopped banana.
1922	Buitoni in Italy produced the 'Kiss'.
1923	In the United States, Frank Mars invented the 'Milky Way'.
1925	Callebaut produced the first chocolate cover.
1925	In New York was established the Cocoa Exchange for trading the raw material, and the United States became a global player in the production of chocolate
1943/5	American troops in Europe distributed their chocolate bars
1950-1975	In France were founded Valrhona (1950) and Maison du Chocolat by Robert Linxe. Returned the French to supremacy in quality chocolate.
1956	Birth of 'Mon Cheri', the first Boer chocolate industrially produced.
1963	Rud Läderach, in the laboratory of Ennetbühls, invented "hollow" preprints for pralines
1964	On April 20, release of the first jar of Nutella
1974	Here came Kinder Eggs
1984	Raymond Bonnat and Voiron created the first collection of dark "Grands Crus de Cacao".
1988	Valrhona Guanaja realized the first finger, a cru chocolate,1989 Lindt sold in Italian supermarkets a tablet with 70% cocoa
1993/95	First Salon du Chocolat in Paris, first edition of Eurochocolate in Perugia
1998-2000	Amedei and Domori distributed in Italy tablets from crus.

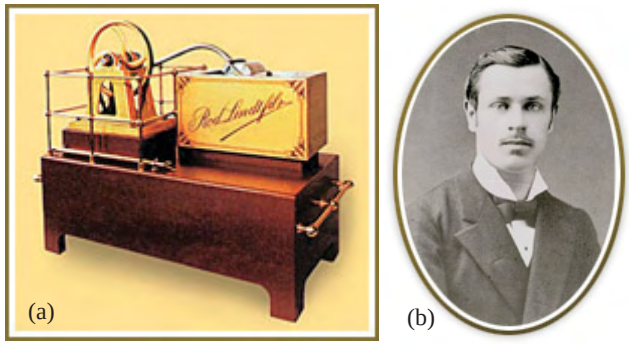

FIG. 4. (a) Conching machine (b) Rudolph Lindt

and looking bright and shiny, it melts in your mouth leaving a pleasant bitter after taste. Should be smooth to the touch - silky, never grainy. The percentage of cocoa is one of the main characteristics determining its quality. The best ones contain at least 70% cocoa.

Gianduja. Brown in colour, this is born from the union of hazelnuts, cocoa and sugar. Sometimes, milk, almonds or walnuts are added. Gianduja was first made in Turin in the mid-19th century.

Milky. Contains not less than 20-25% cocoa, in addition to cocoa butter, sugar, milk powder and lecithin. A good milk chocolate should have a shiny appearance. The scent must be intense and persistent. It has first the smell of vanilla and milk and finally the cocoa must prevail. A good milk chocolate is crisp, but dissolves quickly in the mouth to a slightly mushy paste. Finally, the taste should be sweet with a slight bitter note from the cocoa.

White. This contains cocoa butter, sugar, milk powder and vanilla. It tastes sweet and nice and can also be used to prepare other edibles like mousse, cream and desserts (Fig. 9). Besides edible products, the chocolate can be used for other applications, such as cosmetics, due to the properties of cocoa butter (Fig. 10).

FIG. 5. Posters of movies on the theme of chocolate

FIG. 6. Items made of chocolate

FIG. 7. Jean Etienne Liotard. The chocolate maid

FIG. 8. A Caravaggio theme with chocolate

FIG. 9. Varieties of chocolate

FIG. 10. Alternative uses of chocolate

Chocolate in science and health

So far, we have traced the history of chocolate, but let us not forget science and issues of health.

Chemical and physical properties

These are mainly due to cocoa butter, which is yellow in colour and contains three main triglycerides with oleic acid – a monounsaturated fatty acid: POP (20%), POSt (40%) and StOSt (25%) (P = palmitic acid (saturated); O = oleic acid (monounsaturated); S = stearic acid (saturated)) - and smaller amounts of others containing linolenic and arachidonic acids.[1] Brittle below 20°C, soft between 30-32°C, the butter melts at just below body temperature. It has exceptional nutritional properties for the skin, purifying, soothing and moisturizing (Fig. 11). POP, POSt and StOSt are the abbreviations of triglycerides which make up cocoa butter, but they can also be added from other compounds (generally called cocoa butter substitutes) to cocoa to make chocolate (Fig. 12), e.g., made from illipe butter, Borneo tallow (or Tengkawang Shorea spp) (Fig. 13), palm kernel oil (Elaeis guineensis, Elaeis olifera), fat and stearin of Shorea robusta, shea butter (Butyrospermum parkii), cocum butter (Garcinia indica), kernel oil of mango (Mangifera indica). In chocolate for making ice cream and similar frozen products, coconut oil can be added, but the nutritional value is not the same.

Energy and nutritional content of chocolate

The composition of the various chocolate varieties are summarized in Table 3, while the energy and micronutrients are briefly accounted below:
Pure chocolate = 2080 kilojoules (kJ) or 495 kilocalories (kcal)/100 gm
Milk chocolate = 2160 kilojoules (kJ) or 515 kilocalories (kcal)/100 gm
White chocolate = 2260 kilojoules (kJ) or 540 kilocalories (kcal)/100 gm

Flavonoids. These are antioxidants that act against aging (not present in white chocolate).
Cocoa butter. Confers exceptional nutritional properties for skin. Purifies??, soothes and moisturizes even the driest chapped skin.
Magnesium. Stimulates the growth of skin cells. Invigorates and improves mood.

Caffeine. Stimulant and tones skin.
Theobromine. Stimulates heart muscle and nervous system. Higher concentration in dark chocolate. This micronutrient has the greatest impact on health, but the concentration varies with the variety of chocolate.

Phenylethylamine. Stimulates good humor, and is found in the brains of lovers!

FIG. 11. Cocoa butter

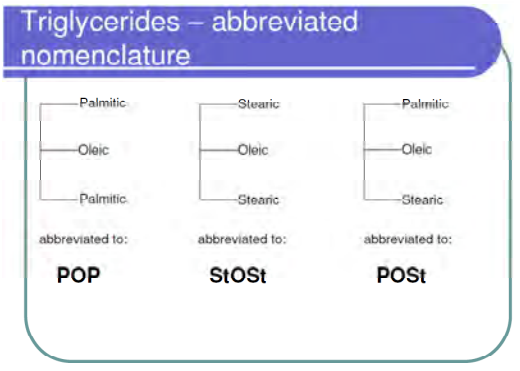

FIG. 12. Main triglycerides in chocolate

FIG. 13. Shorea spp. (origin of illipe butter)

TABLE 3: Nutritional values per 100 grams of different chocolates

	Fondant	Milky	White
Protein (gr)	3.2	7.6	7.5
Lipid (gr)	33.2	33.3	37
Carbohydrate (gr)	60.3	57	52
Pure Lecithin (gr)	0.3	0.3	0.3
Teobromine (gr)	0.6	0.2	/
Ca (mg)	20	220	250
Mg (mg)	80	50	30
P (mg)	130	210	200
Fe (mg)	2	0.8	Traces
Cu (mg)	0.7	0.4	Traces
Vitamin A (IU)	40	300	220
Vitamin B1 (mg)	0.06	0.1	0.1
Vitamin B2 (mg)	0.06	0.3	0.4
Vitamin C (mg)	1.14	3	3
Vitamin D (IU)	50	70	15
Vitamin E (mg)	2.4	1.2	Traces
Kcal	495.2	514.2	538.0

The combination of caffeine, theobromine and phenlethylamine makes you think of a good sweet chocolate, an aphrodisiac and also a base of many cosmetics.

Beneficial effects of chocolate

Along with caffeine and theophylline, theobromine constitutes the methylxanthines (Fig. 14) which are known to enhance the action of cAMP. In fact, they inhibit phosphodiesterases that hydrolyze cAMP to 5 ‘ AMP. Methylxanthines, however, has different concentrations in different chocolates (Table 4).

FIG. 14. Methylxanthines

Earl Wilbur Sutherland was the first to identify the role of cAMP (Fig. 15), and was awarded the Nobel Prize (Physiology/Medicine) in 1971. Sutherland, in addition to influencing my scientific work (Fig. 16), pioneered a great

TABLE 4: Methylxanthine concentrations in different chocolates

Cacao product	**Methylxanthines (mg/g)**
Cacao bean	14-53
Baker’s chocolate	16
Semisweet chocolate	9
Milk chocolate	2
Hot chocolate	0.4
White chocolate	0.05

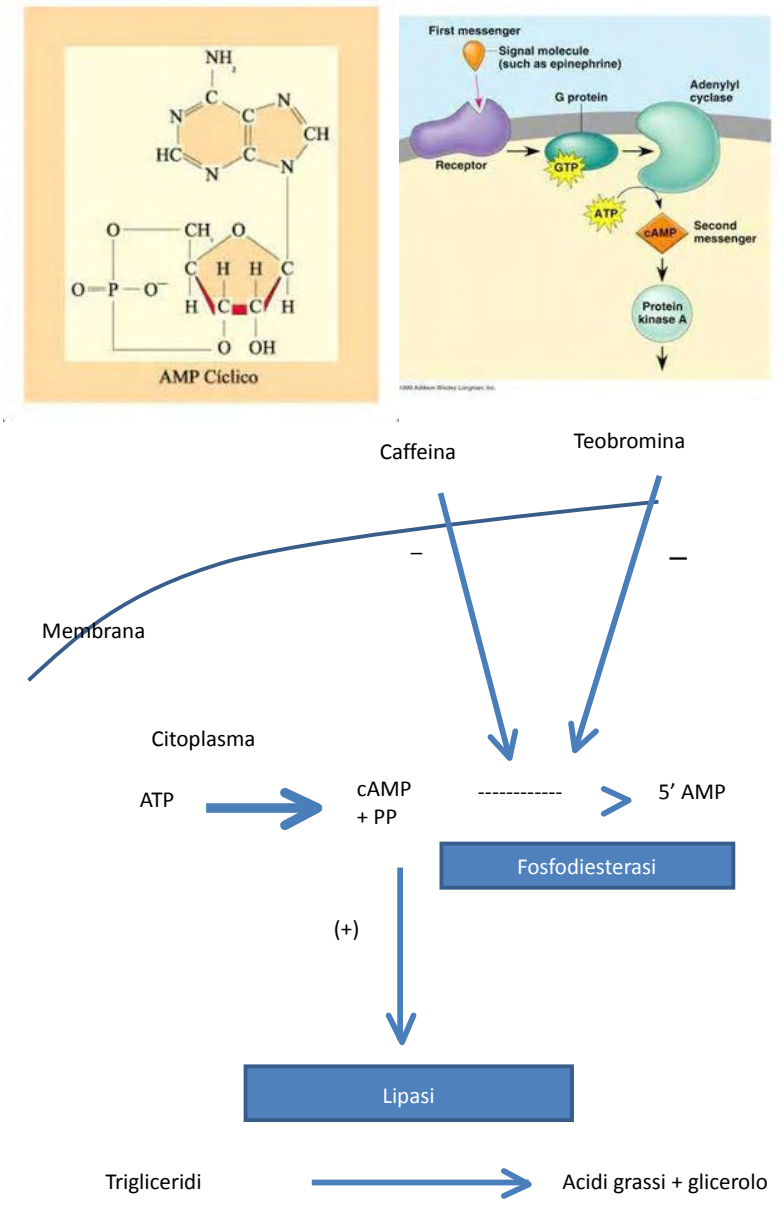

FIG. 15. Mechanism of action of cAMP

FIG. 16. Earl W. Sutherland (in picture), Michael Laposata (front), Roberto Verna (rear)

20 years of enthusiastic scientific study on the transmission of intracellular signals among those I called "the cyclers": Martin Rodbell, Paul Greengard, Pedro Cuatrecasas, Ira Pastan, Michael Gottesman, the first two also awarded the Nobel Prize (Physiology/Medicine) in 1994 and 2000 respectively (Fig. 17).

Chocolate also contains psychoactive substances (Table 5). The beneficial effects

FIG. 17. Some famous "cyclers." From top left: Paul Greengard, Ira Pastan, Martin Rodbell, Pedro Cuatrecasas, Michael Gottesman

of chocolate (Tables 6 and 7) are due to the natural components in cocoa beans, including epicatechin and resveratrol, two powerful antioxidants.

TABLE 6: *Main properties of cocoa beans beneficial to health[2]

Anti-inflammatory
Anti-diabetic and anti-obesity
Cardioprotective
Improves liver functions
Neuroprotective
Improves intestinal flora
Reduces stress hormone
Reduces symptoms of glaucoma and cataract
Retards progression of paradontitis

*Studies published on: http://www.greenmedinfo.com/substance/chocolate

TABLE 5: Psychoactive substances in chocolate

Substance	Action
Dopamine	Many substances that produce pleasure trigger the release of this transmitter in the limbic system: heroin, cocaine, alcohol, nicotine.
Serotonin	Controls mood, and gives the "antidepressant" effect of chocolate.
Anandomide	A lipid (named from a Sanskrit word that means happiness). Present in the brain as an endogenous substance, it interacts with cannabinoid receptors.
Phenylethylamine	Neurotransmitter responsible for the state of mood and pleasure. It has a stimulant effect.

TABLE 7: Beneficial effects of flavonoids

- Increased capillary resistance
- Decreased permeability of vessels
- Anti-inflammatory
- Anti-allergy
- Antiviral
- Antiatherogenic
- Antiarrhythmic
- Antitumor
- Antiepatotoxic
- Immunostimulant
- Lipid-lowering
- Stimulating cognitive functions
- Modulating activity of estrogen
- Improves the bioavailability of nitric oxide (NO), which action improves the pressure, platelet function and increases the fluidity of blood

Vasodilation is the result of nitric oxide (NO) derived from the endothelium. NO is a pluripotent molecule with different effects. The main physiological stimulus for the synthesis of endothelial NO is friction from the flow of blood against the surface of the blood vessel, a process called "flow-mediated vasodilation" (FMD) (Fig. 18).

Furthermore, a variety of agonists, such as acetylcholine, histamine, thrombin, serotonin, adenosine diphosphate (ADP), bradykinin, and norepinephrine, cause vasodilation when the endothelium is intact, overcoming vasoconstriction or if the endothelium is dysfunctional. Finally, NO has many other effects, such as inhibition of platelet adhesion and a synergistic effect with prostacyclin to reduce the expression of tissue factor induced by endotoxin and cytokines, the potential prothrombotic endothelial cell and inhibition of monocytes to the endothelium (Fig. 19).

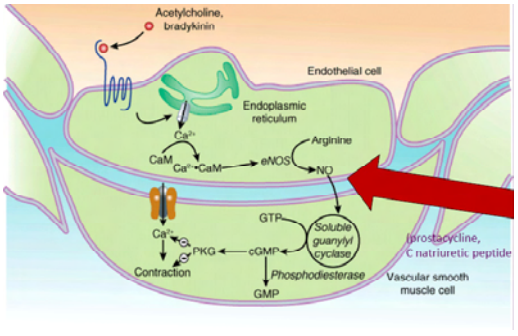

FIG. 18. NO-mediated vasodilation

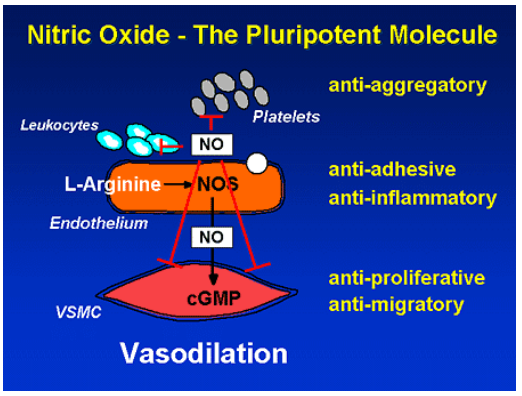

FIG. 19. NO, the pluripotent molecule

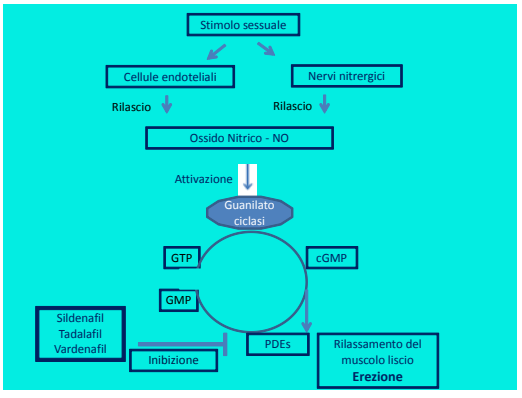

FIG. 20. Mechanism of erection

Luis Ignarro, who was also awarded the Nobel Prize in Physiology or Medicine in 1998, defined the role of NO in erection by the male. He demonstrated that erection is enhanced by drugs that inhibit phosphodiesterase (Fig. 20). Given that chocolate has the same power, would it be useful for this purpose to eat chocolate?

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