The story of

Polymer chemistry

basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

About this booklet

The cover page

The story of polymer chemistry began with the discovery of rubber (a natural polymer), which was found in rubber trees mostly in parts of Africa, India and other countries around the world. The cover page shows a method that was used to collect sap from trees years before the technology of producing polymers from oil in the laboratories became common. Read the story of Congo during the discovery of rubber in that country on the BACK PAGE.

The purpose of this booklet is to provide teachers with a holistic view of polymer chemistry. Some of the discussions entertained in this booklet are provided to support a view of polymer chemistry broader than that provided by the syllabus. Teachers need to know more than their learners so as to make the teaching and learning experience interesting and exciting. **Kindly note that the material covered in this booklet is not necessarily examinable. For examinable material, consult your *Assessment Guideline* document**.

The ***back page*** provides history as well as the impact of colonization on the people of the Democratic Republic of Congo in the pursuit of rubber by Belgium. It is the wish of the African Union (AU) that students of Africa learn about their cultures and the cultures of other Africans as well as colonization and, its impact on the lives of Africans and how it continues to shape their present.

Commerce and innovation, according to the Reconstruction and Development Program (RDP) need to go hand in hand. It is usually in the process of innovation and commerce that human rights tend to be ignored and the brutality of those eager to profit using human labour is unleashed on the unsuspecting population. It is hoped that future scientists and business people will one day put humanity before profits.

Contents

1. Compounds around us

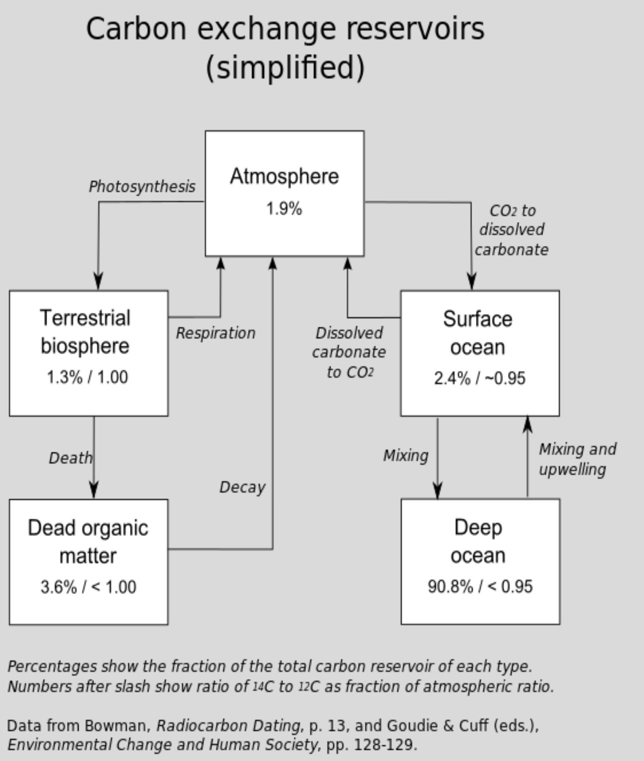
Many naturally occurring compounds have very complicated structures (**Matter and Materials**) that present great challenges to chemists wishing to replicate them. Over the years chemists and ordinary people have found ways of forming (**Chemical Change**) new products (**Matter and Materials**) by reacting substances and providing conditions that facilitate reactions (**Chemical Change**). This has resulted in many synthetic compounds being produced. Many of these compounds resemble naturally occurring compounds while some of the compounds produced do not occur in nature.

Of the 10 million or so compounds that are known today, about 9 million of those are carbon (**C**) containing compounds. Nearly everything around you contains carbon in an organic compound: artificial nails, gas, petrol, oil, most of the medicines you take, the plastics you encounter are all organic based compounds.

The Greek word *plasticós* means "to mold." All plastics were soft and moldable during their production - that's why they're called *plastics*. You can form nearly any object out of plastics from bristles on toothbrushes to bulletproof vests to fibers for making textiles for clothes. There are hard plastics and soft plastics, clear ones and colorful ones, and plastics that look like leather, wood, or metal. Plastics have changed the world. (This explains why the study of organic compounds is important!)

Most plastics are made from monomers found in oil. Plastics are man-made materials. They are a useful invention because they are waterproof, easy to shape and tough. They have taken the place of traditional materials like cotton, wool, wood and metal in many products. Plastic is made from non-renewable resources and takes a very long time to decay.

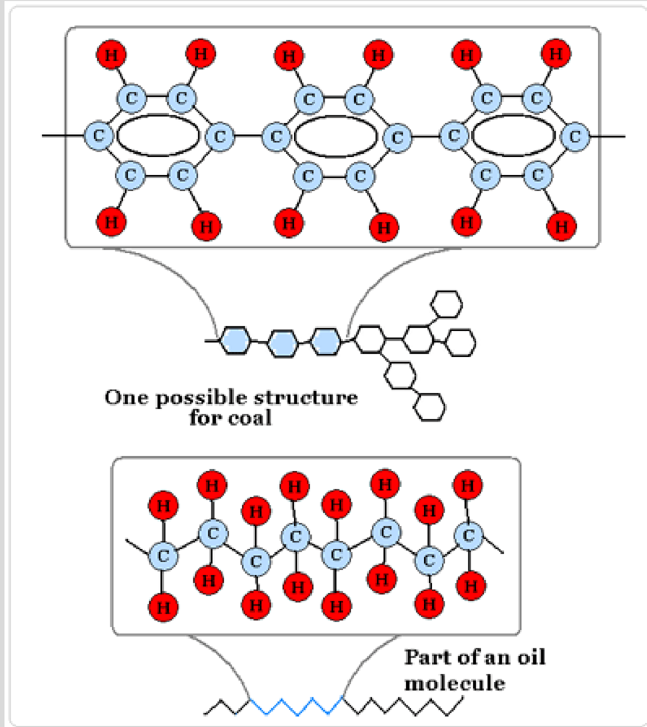
1.1 Carbon everywhere around you!



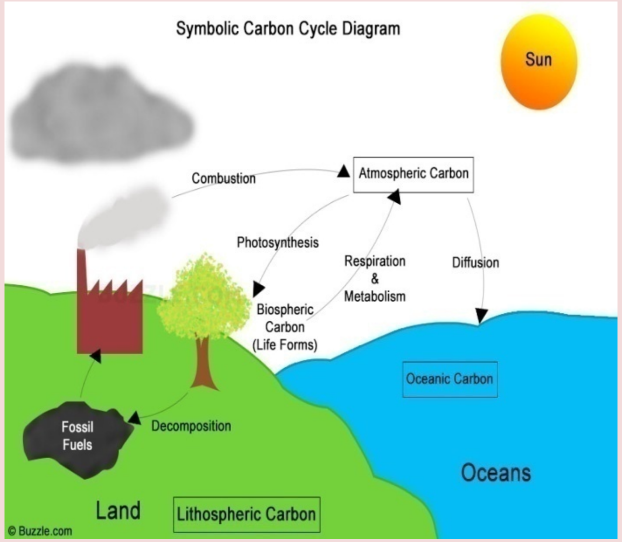
Carbon in coal

A fossil fuel, coal forms when dead plant matter is converted into peat, which in turn is converted into lignite, then sub-bituminous coal, after that bituminous coal, and lastly anthracite.

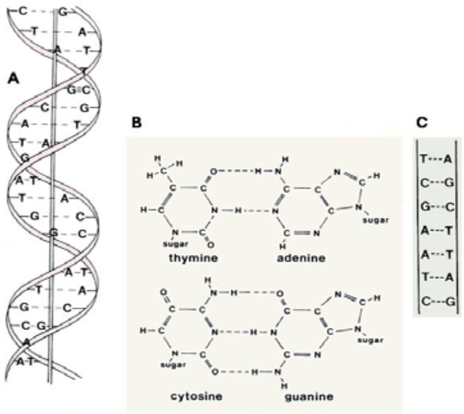
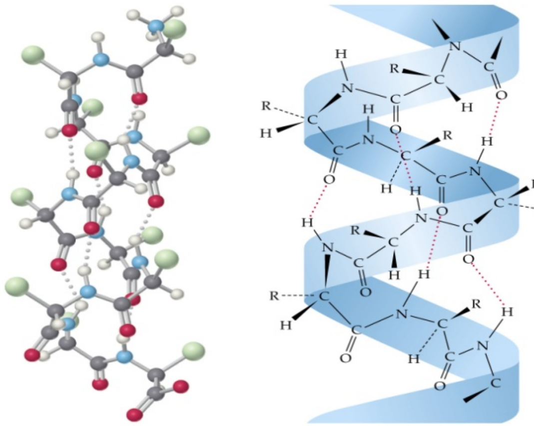
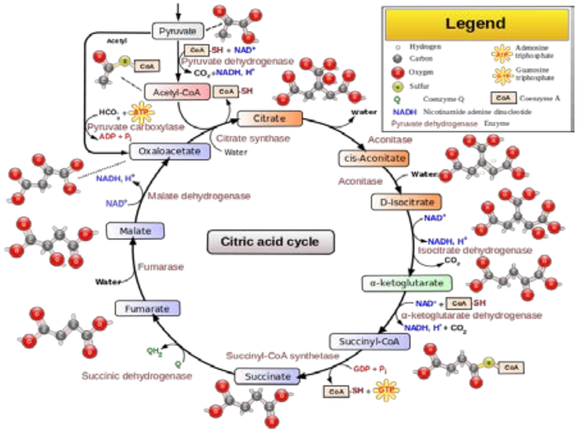
http://en.wikipedia.org/wiki/File:Coal_anthracite.jpg



http://www.green-planet-solar-energy.com/fossil-fu formation.html

 Cycle of Carbon http://www.buzzle.com/images/diagrams/carbon - cycle.jpg	**Carbon Sources** Carbon sources refer to all the elements - organic or inorganic, which release Carbon in some form into the atmosphere. Here are the sources: • Volcanic eruptions • Respiration of animals and humans • Decay of dead matter • Combustion of fossil fuels • Natural processes like conversion of limestone to lime, metamorphism of rocks, etc. Warm water bodies Read more at Buzzle: http://www.buzzle.com/articles/the-carbon-cycle-for-kids.html **Carbon Sinks** • Carbon sources refers to all the elements - organic or inorganic, which release Carbon in some form into the atmosphere. Here are the sources: • Plants, algae, and a few strains of bacteria • Cold water bodies • Landfills (artificial sink)	**Carbon Reservoirs** Reservoirs of Carbon are those which store this element in forms, for small or really long periods of time. They are: The Earth's atmosphere, which contains copious amount o Organic elements like rocks, soil, sediments, limestone and etc. Oceans which also contain a lot of dissolved Carbon in vari well in the form of fossil fuels. Volcanic eruptions and geo activities also release a lot of Carbon into the atmosphere Read more at Buzzle: http://www.buzzle.com/articles/the- kids.html

1.2 Carbon in our bodies

 **DNA** http://www.tutorhelpdesk.com/homeworkhelp/Biology-/Structure-Of-Dna-Assignment-Help.html	**Keratin**  http://itech.dickinson.edu/chemistry/?cat=69n	**Krebs Cycle**  http://simple.wikipedia.org/wiki/File:Citric_acid_cycle_with_aconitate_2.svg (see enlarged diagram on the last page)
DNA is deoxyribonucleic acid (DNA), it contains the biological instructions that make each species unique. Passed on from generation to generation and principally responsible for the features that children share with their parents.	Keratin is a fibrous protein. Alpha keratins are found in mammals only and makeup of hair, nails, horns, hooves and claws. Beta keratins are present in birds, reptiles and amphibians forming claws, nails scales, shells, feathers and beaks.	The **Krebs cycle** (or **citric acid cycle**) is a part of cellular respiration. It is a series of chemical reactions used by all aerobic organisms to generate energy. It is import to many biochemical pathways.

2. The Chemistry of plastics

(Consider Plastics to be at Macro level of understanding chemistry and polymers at molecular or micro level.)

Plastics are *synthetic* materials, which mean that they are artificial, or manufactured. *Synthesis* means that "something is put together," and synthetic materials are made of building blocks that are put together in factories. Plastics are made of polymers which are obtained from monomers (low-molecular-weight) by polymerization reactions, in which large numbers of monomer molecules are linked together. Plastics are polymers, but polymers don't have to be plastics. The way plastics are made is actually a way of imitating nature and also producing synthetic substances that nature never produced. This has created a huge number of polymers. Cellulose, the basic component of plant cell walls is a polymer, and so are all the proteins produced in your body and the proteins you eat. Another famous example of a polymer is DNA - the long molecule in the nuclei of your cells that carries all the genetic information about you. See page 8.

People have been using natural polymers, including silk, wool, cotton, wood, and leather for centuries. These products inspired chemists to try to create synthetic counterparts, which they have done with amazing success. These synthetic counterparts have properties similar to the natural ones. (**Matter and Material; Chemical Change)**

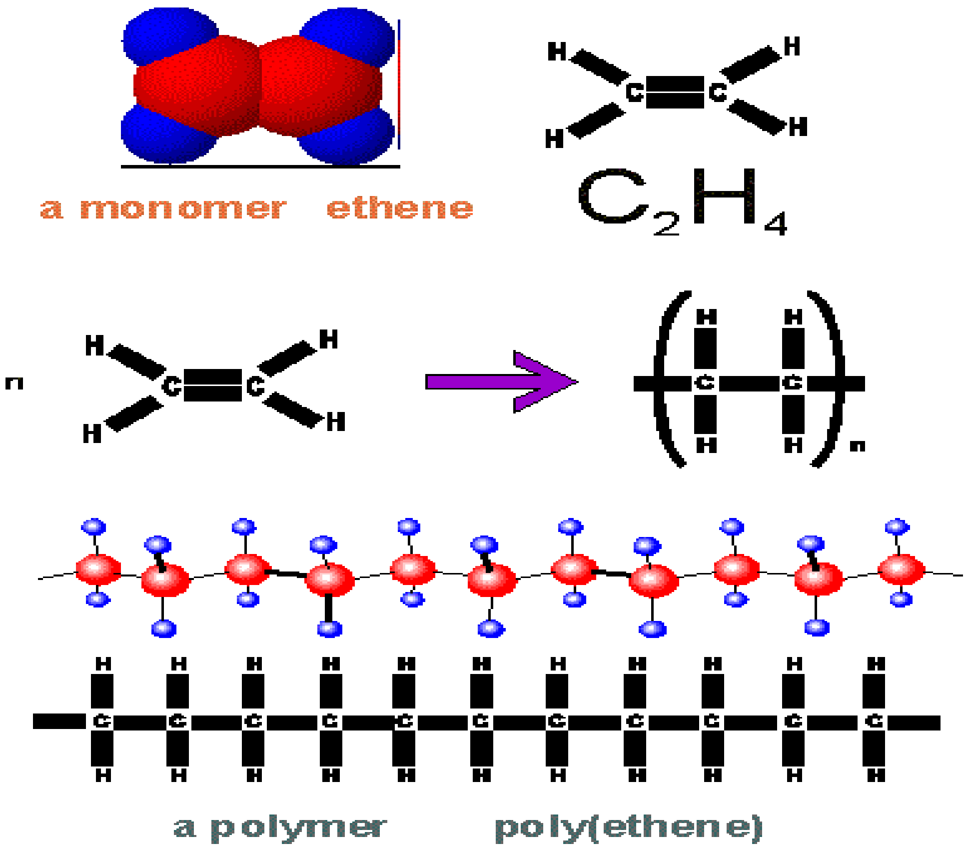
The building blocks for making plastics are small *organic* molecules - molecules that contain carbon along with other substances. They generally come from oil (petroleum) or natural gas, but they can also come from other organic materials such as wood fibers, corn, or banana peels! Crude oil, the unprocessed oil that comes out of the ground, contains hundreds of different hydrocarbons, as well as small amounts of other materials. The job of an oil refinery is to separate these materials and also to break down (or "crack) large hydrocarbons into smaller ones. A petrochemical plant receives refined oil containing the small monomers they need and creates polymers through chemical reactions. Plastics factories then buys the end products of a petrochemical plant - polymers in the form of resins - introduces additives to modify or obtain desirable properties, then molds or otherwise forms the final plastic products that have properties and qualities that the factory requires.

2.1 Polymers

Each of these small molecules is known as a *monomer* ("one part") because it's capable of joining with other monomers to form very long molecule chains called *polymers* ("many parts") during a chemical reaction called ***polymerization*****.** For this to happen the conditions must be conducive. Conditions would involve temperature, catalysts and available monomers amongst other.

The process by which we get a polymer is called **polymerization**. This process has three stages: In the first stage, the bond in a monomer is split into two identical parts, (usually referred to as 'a bond is **homolytically** cleaved, producing two radicals') each with an unpaired electron (or free electron). Now we have a free radical (A molecule with an unpaired electron). The free radical (second line in the image on page 11), forms a new bond with a "neighbour atom." This process repeats over and over again to form large chains containing thousands of carbon atoms. To visualize this, think of a single paper clip as a monomer, and all the paper clips in a box chained together as a polymer. (*There are processes outside the scope of this booklet that are usually involved in order to have control on the length, branching and other characteristics of the chain).*

Eventually chain termination will occur. The mechanism involves the reaction between two growing chain ends. The two radicals eventually couples and the process comes to an end.



Polymerization of ethene (See section 2.5 for further discussions).

EXAMPLES OF PLASTICS

Clockwise: PVC, Memorabilia Case, Acrylic, polystyrene, Bottles made of Pet, Nylon, Man-made Rubber Sole

2.2 Main Types of plastics: Thermoplastic and Thermosetting

2.2.1 THERMOPLASTIC Plastics that *can* be reshaped

Thermoplastics can be heated, moulded and shaped various ways, lots of times. Each time a thermoplastic is heated, it tries to return to the shape it first was, usually a flat sheet. This is called **plastic memory**. Thermoplastics are usually softer than thermosetting plastics and usually melt at lower temperatures, so are not as suitable for casings on electrical.

Thermoplastics have long, linear polymer chains that are only weakly chemically bonded, or connected, to each other. When a thermoplastic object is heated, these bonds are easily broken, which makes the polymers able to glide past each other like strands of freshly cooked spaghetti. That's why thermoplastics can readily be remolded.

There is a huge range of uses including plastic wrap, food containers, lighting panels, garden hoses, and the constantly encountered plastic bag. The weak bonds between the polymers reform when the plastic object is cooled, which enable it to keep its new shape. Thermoplastics are easy to recycle since they can be melted and reshaped into other products. For example, a plastic bottle that contained a soft drink could be reformed into the fibres of a fleece jacket.

2.2.2 THERMOSETTING Plastics that *can't* be reshaped

Thermosetting plastics are generally strong and resistant to heat, but they melt the first time they are heated to a high enough temperature and harden (set) permanently when cooled. They can never be melted or reshaped again. They are used in situations where resistance to heat is important, e.g. on kitchen work surfaces, good-quality plastic cups, saucepan handles and plug casings equipment. http://www.petervaldivia.com/technology/plastics/
The linear chains are cross linked - strongly chemically bonded. This prevents a thermoplastic object from being melted and reformed

Thermosets are good to use for things that will be warmed up such as spatulas and other kitchen tools. They're also used in glues, varnishes, and in electronic components such as circuit boards. Thermosets are also hard to recycle, but today there are methods of crushing the objects into a fine powder form for use as fillers in reinforced thermosets.

Is Polystyrene a thermoset or a thermoplastic?

2.3 The evolution of polymer chemistry from rubber (Matter and Materials)

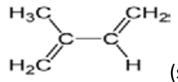
2.3.1 Natural rubber

"**Natural rubber**, also called **India rubber** or ***caoutchouc***, as initially produced, consists of suitable polymers of the organic compound isoprene, with minor impurities of other organic compounds plus water. Forms of polyisoprene that are useful as natural rubbers are classified as elastomers. Currently, rubber is harvested mainly in the form of the latex from certain trees. The latex is a sticky, milky colloid drawn off by making incisions into the bark and collecting the fluid in vessels in a process called "tapping". (See cover picture).The latex then is refined into rubber ready for commercial processing. Natural rubber is used extensively in many applications and products, either alone or in combination with other materials. In most of its useful forms, it has a large stretch ratio, high resilience, and is extremely waterproof." Wiki(http://en.wikipedia.org/wiki/Natural_rubber

Rubber was known to the indigenous peoples of the Africa, Americas and India long before the arrival of European explorers.

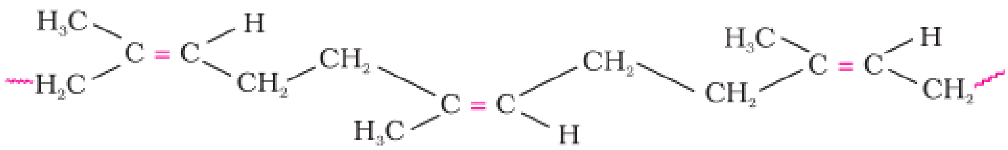
- When Christopher Columbus visited Haiti, he observed natives playing ball. The balls of Haiti were incomparably superior toys to their own, and they bounced better . These high bouncing balls, he later learned were made from a milky fluid, the consistency of honey, which the natives harvested by tapping certain trees and then cured over the smoke of palm nuts. Africans and Mexicans also used it as a ball.
- It was also used for lighting in many indigenous communities..
- In India, it had been used for making waterproof sandals

*Find out from **your grandmother or from stories in your culture what the other uses of rubber were in Africa.***

Natural rubber, also called **India rubber** or ***caoutchouc***, as initially produced, consists of suitable polymers of the organic compound isoprene, C_5H_8 

(structure).

The polymer of this monomer would join with minor impurities of other organic compounds plus water. Forms of polyisoprene that are useful as natural rubbers are classified as elastomers. Currently, rubber is harvested mainly in the form of the latex (an emulsion of polymer microparticles in an aqueous medium) from certain PLANTS. Latex as found in nature is a milky fluid found in 10% of flowering plants. The latex is a sticky, milky colloid drawn off by making incisions into the bark and collecting the fluid in vessels in a process called "tapping" (see cover of this booklet).The latex then is refined into rubber



Natural rubber

2.3.2 Contemporary manufacturing

The first commercial use of rubber was as as an eraser (hence the name rubber for erasers). Elsewhere it has since been used to make jars replacing the leather *borrachas* that the Portuguese used to ship wine. It has also been used to produce flexible tubes. Since then, countless craftsmen have become involved with rubber; making many things from this wonderful natural product. In the early stages of understanding rubber, waterproof fabrics and snow-boots were produced in New England. Unfortunately, cold weather affected goods made from non-vulcanized natural rubber leaving them brittle and with a tendency to gum together if left in the sun, all discouraging consumers. (this highlights matter and materials as well as chemical change).

Around 25 million tons of rubber is produced each year, of which 42 percent is natural rubber. The remainder is synthetic rubber derived from petrochemical sources. Around 70 percent of the world's natural rubber is used in tires. The top end of latex production results in latex products such as surgeons' gloves, condoms, balloons and other relatively high-value products. The mid-range which comes from the technically-specified natural rubber materials ends up largely in tires but also in conveyor belts, marine products and miscellaneous rubber goods. Natural rubber offers good elasticity, while synthetic materials tend to offer better resistance to environmental factors such as oils, temperature, chemicals or ultraviolet light and suchlike. "Cured rubber" is rubber which has been compounded and subjected to the vulcanisation process which creates cross-links within the rubber matrix Wiki

2.4 Chemical Change- making rubber products

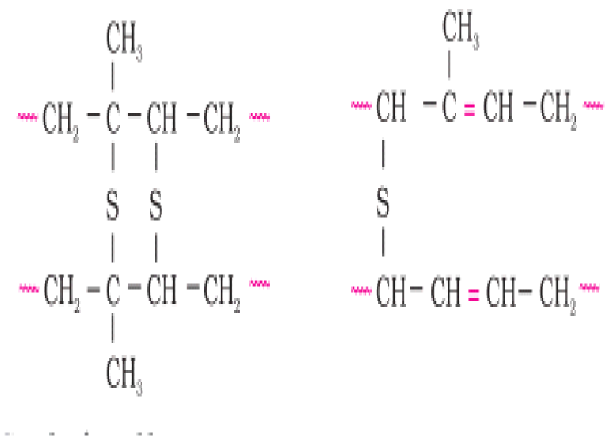
2.4.1 Vulcanised rubber (An example of *materials and Chemical Change*)

Reacting natural rubber with Sulfur

The vulcanization process was discovered in 1839, by accident. The strange substance from the jungles of the tropics had been mastered. It remained, however, to perfect the process, to ascertain the accurate formula and the exact degree of heat. This process opened doors to many experiments by many people, chemists and non chemists.

Natural rubber is often vulcanized, a process by which the rubber is heated and **sulfur**, **peroxide or bisphenol** are added to improve resistance and elasticity, and to prevent it from perishing. The development of vulcanization is most closely associated with Charles Goodyear in 1839. Before World War II era manufacturing, carbon black was often used as an additive to rubber to improve its strength, especially in vehicle tires. Today, all vehicle tires are made of synthetic rubbers.

Molecular structure of vulcanized rubber (Check the Sulfur atoms)



2.4.2 Difference between Vulcanized rubber and Natural rubber

The vulcanized rubber has properties that are just opposite to that of natural rubber. These properties are:

- excellent elasticity.
- low water absorption tendency
- resistance to the action of organic solvents
- resistance to attack of oxidizing agents.

2.4.3 Main synthetic rubber production system

A wide variety of synthetic rubbers have been developed since the vulcanisation of rubber was first discovered. As massive investments were required to develop these different varieties, the production technology was heavily concentrated in long-established global enterprises.

Many products, requiring different atoms have since been produced. Today, polymers have replaced materials such as steel, wood, paper and cotton etc. The properties of polymers are useful in industry and in the lives of people. The study of polymers chemistry affords you an opportunity of knowing what is available in nature and what can be mimicked in the laboratories.

It is important to notice how an atom bonded to a particular molecule changes the properties of such a molecule **(Chemical Change).** It is also important to notice how the nature of the bonds influences the properties of molecules **(Matter and Materials). The conditions under which such reactions are possible are also very important. You will note that many of these reactions happen in basic conditions (Acids and Bases) at particular temperatures!!!**

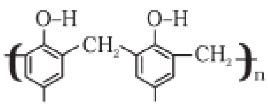
The different sections that we study in chemistry are therefore very important and it is up to the teachers to show the relationships between the various chapters.

Note the monomers that make up some of the most common plastics that you come into contact with everyday. Consult the safety cards and check out the properties of these monomers!

It is important to note that the monomers necessary for these reactions do not necessarily need to come from rubber. Most of these monomers can be sourced from oil through fractional distillation. Oil is not only important as a fuel but it is also important as a source of monomers. These monomers are used for many synthetic products

2.4.4 Polymers around you

Table 15.1: Some Other Commercially Important Polymers

Name of Polymer	Monomer	Structure	Uses
Polypropene	Propene	$\left(CH_2\text{-}CH(CH_3) \right)_n$	Manufacture of ropes, toys, pipes, fibres, etc.
Polystyrene	Styrene	$\left(CH_2\text{-}CH(C_6H_5) \right)_n$	As insulator, wrapping material, manufacture of toys, radio and television cabinets.
Polyvinyl chloride (PVC)	Vinyl chloride	$\left(CH_2\text{-}CH(Cl) \right)_n$	Manufacture of rain coats, hand bags, vinyl flooring, water pipes.
Urea-formaldehyde Resin	(a) Urea (b) Formaldehyde	$\left(NH\text{–}CO\text{–}NH\text{–}CH_2 \right)_n$	For making unbreak-able cups and laminated sheets.
Glyptal	(a) Ethylene glycol (b) Phthalic acid		Manufacture of paints and lacquers.
Bakelite	(a) Phenol (b) Formaldehyde		For making combs, electrical switches, handles of utensils and computer discs.

http://textbook.s-anand.net/wp-content/uploads/2011/08/15_31.png

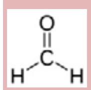
2.4.5 More examples of organic molecules: Focus on Aldehydes and Ketones (Functional Isomers)

(Some of these molecules could be recognizable as monomers in polymers you might know.)

Formaldehyde and acetone are generally associated with nail hardeners and nail enamel remover. In chemical terms, these substances belong to the substance class of aldehydes and ketones - which are well-known molecules in cosmetic products like e.g. preservatives, perfumes or essential oils.

Aldehydes and ketones are oxygen-containing hydrocarbons and can be found in abundance in natural surroundings but also in combination with chemical processes. They are formed with the **oxidation of alcohol (What do you understand by the oxidation of alcohols?)** for instance. The low molecular molecules are used in cosmetic products because of their flowery notes and solvent characteristics. Aldehydes and ketones also are known for their chemical reactivity and that is the reason they are used in antimicrobial activity.

Formaldehyde (How ***many carbon atoms?)*** is not equipped with an agreeable fragrance though, as a matter of fact even in small concentrations it has a pungent and acrid smell that irritates eyes and respiratory tract. Due to the high reactivity of formaldehyde with nitrogen-containing substances like proteins respectively amino acids, it is used as a **disinfecting agent and preservative.**



formaldehyde

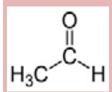
Since formaldehyde has meanwhile been classified as a carcinogenic substance, its use in cosmetic products is subject to strong restrictions (KVO - German Cosmetic Decree): **"Every finished product containing formaldehyde and those that release formaldehyde are subject to be labeled "containing formaldehyde" as far as the concentration of**

formaldehyde in the finished product exceeds 0.05 %." Nail hardeners may contain concentrations of about 5 % though. Once applied on the nails it cross-links with the protein structures of the **keratin in the nails** similar to cross-linkage processes in plastics manufacturing. (***Do you know the chemical properties of compounds that are used on your nails, nail hardener, shampoo, hair extensions etc? Check them out on the safety cards)***

Formaldehyde use declining

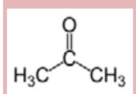
Formaldehyde is less and less often used as a preservative in cosmetic products. It has to be mentioned though that quite a few formaldehyde releasers as e.g. imidazolidinyl urea are still being added. In case that this substance reacts within the skin, the complete formaldehyde content will be released. That is why formaldehyde releasers have the same allergenic potential as formaldehyde itself. Formaldehyde releasers are completely scentless though. This shows how important it is to read the labels on products. Insist on labels on all products. Read these labels and research on these labels.

In the human body, **acetaldehyde** is formed during the oxidation process of ethanol. Traces may be contained in essential oils; however it is not used in cosmetic products. Its tetramer (metaldehyde) even is explicitly banned from cosmetic products.



acetaldehyde

Acetone is a major solvent agent and used as nail enamel remover. In combination with the disinfecting, hair bleaching or universal bleaching agent hydrogen peroxide, highly reactive acetone peroxide (APEX) may form. That is why you should be careful with your waste material!



acetone

Glutaraldehyde belongs to the dialdehydes: both ends of a chain of 5 carbon atoms have a carbonyl function (C=O) attached. It is used for disinfecting and preservative purposes.

Glutaraldehyde is banned in aerosols and the maximal concentration allowed is 0.1 %. It is subject to the warning label "contains glutaraldehyde".

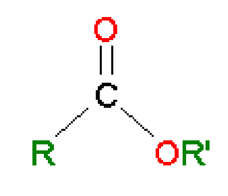
Ketones are produced normally by the liver as part of fatty acid metabolism. In normal states these ketones will be completely metabolised so that very little, if any at all, will appear in the urine. If for any reason the body cannot get enough glucose for energy it will switch to using body fats, resulting in an increase in ketone production making them detectable in the blood and urine.

http://www.dermaviduals.com/english/publications/ingredients/fragrance-sample-aldehydes-and-ketones.html

2.4.6 Esters in Nature and Society

Esters encompass a large family of organic compounds with broad applications in medicine, biology, chemistry and industry. Esters occur naturally in plants and animals. Small molecules of esters, in combination with other volatile compounds, produce the pleasant aroma of fruits. In general, a symphony of chemicals is responsible for specific fruity fragrances; however, very often one single compound plays a leading role. For example, an artificial pineapple flavour contains more than twenty ingredients but ethyl butyrate is the major component that accounts for the pineapple-like aroma and flavour. Fragrances and flavours can be prepared by simply changing the number of carbons and hydrogens (the (alkyl (R) groups) in the ester. (**Materials and Chemical Change)**.

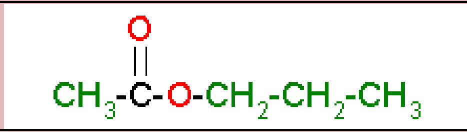
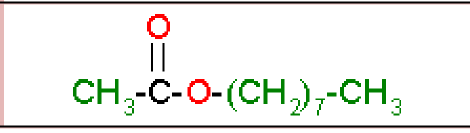
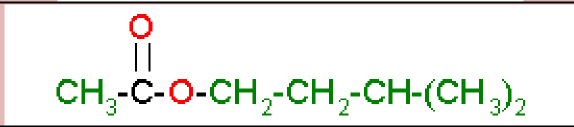
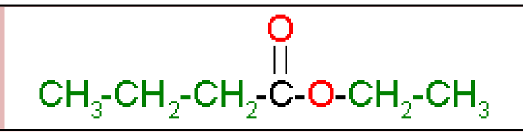
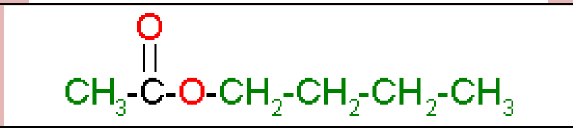
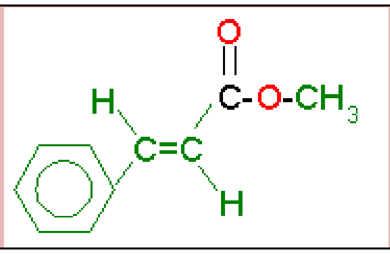
The structure of an ester is represented by the following arrangements of atoms:



(R and R represent different arrangements of carbon and hydrogen)

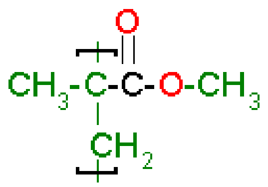
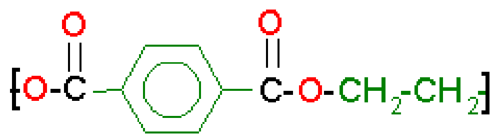
The following table gives ester flavours and fragrances (notice the similarities/differences in the alkyl groups):

It is important to know exactly where each atom is placed in the molecule (**Matter and Materials**)

Name	Chemical Structure of ester	Flavour or Fragrance
Propyl acetate		**Pears**
Octyl acetate		**Oranges**
Isoamyl acetate		**Banana**
Ethyl Butyrate		**Pineapple**
Butyl acetate		**Apple**
Methyl trans-cinnamate		**Strawberry**

Some esters play an important role in insect communication. Isoamyl acetate, the main component of banana aroma, is also the alarm pheromone of the honeybee. (Z)-6-dodecen-4-olide, a circular ester, is the "social scent" of the black-tailed deer. Circular esters (called lactones) are also found in the oily poisonous secretion of termites.

Esters also have remarkable applications in everyday life. Plexiglas is a stiff, transparent plastic made of long chains of esters. Dacron, a fiber used for fabrics, is polyester ('many esters').

Plexiglas	Dacron
	

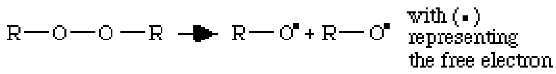
2.4.7 Some interesting polymers (Check out the monomers on the safety cards)

Common plastics and uses	Special-purpose plastics
Common plastics and uses *Polypropylene (PP)* *Food containers, appliances, car fenders (bumpers).* *Polystyrene (PS)* *Packaging foam, food containers, disposable cups, plates, and cutlery, CD and cassette boxes.* *High impact polystyrene (HIPS)* *fridge liners, food packaging, vending cups.* *Acrylonitrile butadiene styrene (ABS)* *Electronic equipment cases (e.g. computer monitors, printers, keyboards).* *Polyethylene terephthalate (PET)* *Carbonated drinks bottles, jars, plastic film, microwavable packaging.* *Polyester (PES)* *Fibers, textiles.* *Polyamides (PA) (Nylons)* *Fibers, toothbrush bristles, fishing line, under-the-hood car engine mouldings.* *Poly(vinyl chloride) (PVC)* *Plumbing pipes and guttering, shower curtains, window frames, flooring.* *Polyurethanes (PU)* *cushioning foams, thermal insulation foams, surface coatings, printing rollers. (Currently 6th or 7th most commonly used plastic material, for instance the most commonly used plastic found in cars).* *Polycarbonate (PC)* *Compact discs, eyeglasses, riot shields, security windows, traffic lights, lenses.* *Polyvinylidene chloride (PVDC) (Saran)* *Food packaging.* *Polyethylene (PE)* *Wide range of inexpensive uses including supermarket bags, plastic bottles.* *Polycarbonate/Acrylonitrile Butadiene Styrene (PC/ABS)* *A blend of PC and ABS that creates a stronger plastic. :Car Interior and exterior parts*	***Special-purpose plastics*** *Polymethyl methacrylate (PMMA)* *contact lenses, glazing (best known in this form by its various trade names around the world, e.g., Perspex, Oroglas, Plexiglas) fluorescent light diffusers, rear light covers for vehicles.* *Polytetrafluoroethylene (PTFE) (trade name Teflon)* *Heat-resistant, low-friction coatings, used in things like non-stick surfaces for frying pans, plumber's tape and water slides.* *Polyetheretherketone (PEEK) (Polyetherketone)* *Strong, chemical- and heat-resistant thermoplastic, biocompatibility allows for use in medical implant applications, aerospace mouldings. One of the most expensive commercial polymers.* *Polyetherimide (PEI) (Ultem)* *A high temperature, chemically stable polymer that does not crystallize.* *Phenolics (PF) or (phenol formaldehydes)* *high modulus, relatively heat resistant, and excellent fire resistant polymer. Used for insulating parts in electrical fixtures, paper laminated products (e.g. "Formica"), thermally insulation foams. It is a thermosetting plastic, with the familiar trade name Bakelite, that can be moulded by heat and pressure when mixed with a filler-like wood flour or can be cast in its unfilled liquid form or cast as foam, e.g. "Oasis". Problems include the probability of mouldings naturally being dark colours (red, green, brown), and as thermoset difficult to recycle.* *Urea-formaldehyde (UF)* *one of the aminoplasts and used as multi-colorable alternative to Phenolics. Used as a wood adhesive (for plywood, chipboard, hardboard) and electrical switch housings.* *Melamine formaldehyde (MF)* *one of the aminoplasts, and used a multi-colorable alternative to phenolics, for instance in mouldings (e.g. break-resistance alternatives to ceramic cups, plates and bowls for children) and the decorated top surface layer of the paper laminates (e.g. "Formica").* *Polylactic acid* *a biodegradable, thermoplastic, found converted into a variety of aliphatic polyesters derived from lactic acid which in turn can be made by fermentation of various agricultural products such as corn starch, once made from dairy products.*

2.5 Polymerisation

2.5.1 The making of polymers from monomers

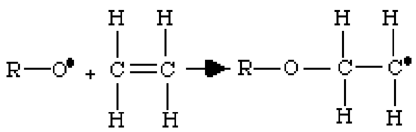
In chain-reaction polymerization, the catalyst can be a free-radical peroxide added in relatively low concentrations. A free-radical is a chemical component that contains a free electron that forms a covalent bond with an electron on another molecule. The formation of a free radical from organic peroxide is shown below:



In this chemical reaction, two free radicals have been formed from the one molecule of R_2O_2. Now that all the chemical components have been identified, we can begin to look at the polymerization process.

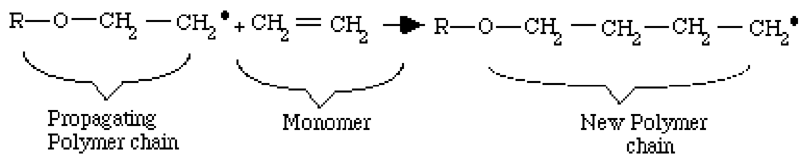
Step 1: Initiation

The first step in the chain-reaction polymerization process, initiation, occurs when the free-radical catalyst reacts with a double bonded carbon monomer, beginning the polymer chain. The double carbon bond breaks apart, the monomer bonds to the free radical, and the free electron is transferred to the outside carbon atom in this reaction.



Step 2: Propagation

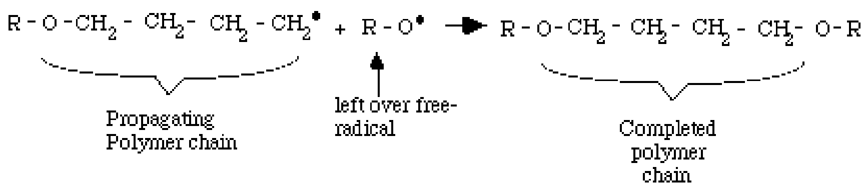
The next step in the process, propagation, is a repetitive operation in which the physical chain of the polymer is formed. The double bond of successive monomers is opened up when the monomer is reacted to the reactive polymer chain. The free electron is successively passed down the line of the chain to the outside carbon atom.

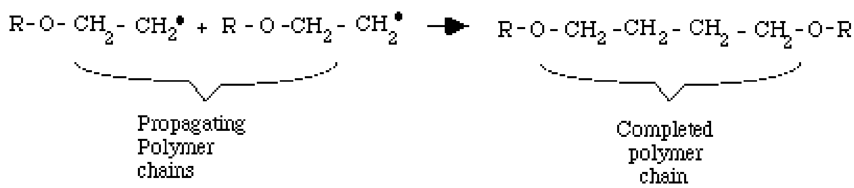


This reaction is able to occur continuously because the energy in the chemical system is lowered as the chain grows. Thermodynamically speaking, the sum of the energies of the polymer is less than the sum of the energies of the individual monomers. Simply put, the single bounds in the polymeric chain are more stable than the double bonds of the monomer.

Step 3: Termination

Termination occurs when another free radical ($R\text{-}O^{\cdot}$), left over from the original splitting of the organic peroxide, meets the end of the growing chain. This free-radical terminates the chain by linking with the last $CH_2^{\cdot}$ component of the polymer chain. This reaction produces a complete polymer chain. Termination can also occur when two unfinished chains bond together. Both termination types are diagrammed below. Other types of termination are also possible.



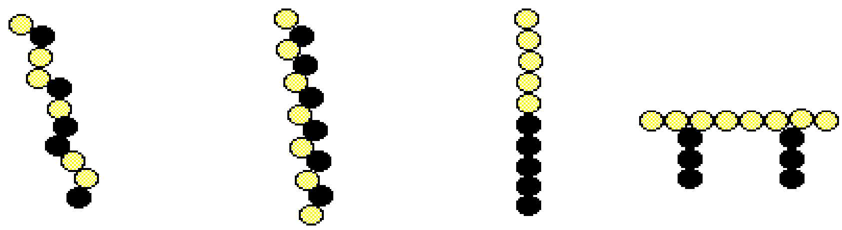


This exothermic reaction occurs extremely fast, forming individual chains of polyethylene often in less than 0.1 second. The polymers created have relatively high molecular weights. It is not unusual for branches or cross-links with other chains to occur along the main chain.

2.5.2 Polymer Chemical Structure

The monomers in a polymer can be arranged in as linear, branched, or cross-linked. Linear polymers are made up of one long continuous chain, without any excess appendages or attachments. This requires particular conditions. Branched polymers have a chain structure that consists of one main chain of molecules with smaller molecular chains branching from it. A branched chain-structure tends to lower the degree of crystallinity and density of a polymer. Cross-linking in polymers occurs when primary valence bonds are formed between separate polymer chain molecules.

Chains with only one type of monomer are known as homopolymers. If two or more different type monomers are involved, the resulting copolymer can have several configurations or arrangements of the monomers along the chain. The four main configurations are depicted below:



Random Copolymers: Different monomers are randomly arranged within the polymer chains.

Alternating Copolymers: Different monomers show a definite ordered alternation.

Block Copolymers: Different monomers are arranged in long blocks of each monomer.

Graft Copolymers: Appendages of one type of monomer are grafted to a long chain of the other.

3. Plastics, society, and the environment

Plastics have contributed to our quality of life in countless ways. Many products would be much more expensive - or wouldn't exist - if it weren't for plastics. Yet, as with the use of any material, there are environmental benefits and impacts.

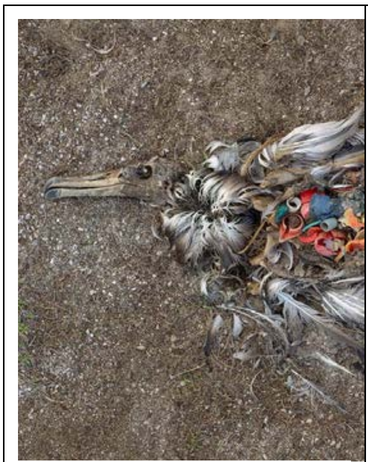
Firstly, there is an environmental impact from plastics production- energy, water use, chemicals used during production as well as waste generation during the manufacturing processes.

Secondly, during their lives, plastic products can save energy and reduce carbon dioxide emissions in a variety of ways. For example, they're lightweight, so transporting them is energy efficient. And plastic parts in cars and airplanes reduce the weight of those vehicles and therefore less energy is needed to operate them and lower emissions are created. http://www.nobelprize.org/educational/chemistry/plastics/readmore.html. Can you think of any other pros and cons regarding plastics?

3.1 Plastic soup in the pacific

What is often termed plastic soup is a stretch of plastic waste starting from about 500 miles off the California coast going past Hawaii and almost reaching Japan. This plastic soup is made up of gallon milk jugs, plastic wrappers, plastic shells that surround virtually every product we buy - millions of tons of plastic, held in place for the ever moving ocean currents.

For us, it's out of sight, out of mind. But not for the wild life! Think before you buy, think before you throw away! The following pictures show part plastic soup in the Pacific Ocean.

http://www.abc.net.au/worldtoday/content/2012/s3418575.htm

http://www.abc.net.au/worldtoday/content

In the US, 2 million bottles are used every 5 minutes! (source:superdumpa/flickr)

http://www.rtcc.org/2012/01/27/micro-plastic-. How%E2%80%98soup%E2%80%99-the-oceans%E2%80%99-hidden-threat/#sthash.t8ImA0Ib.dpuf

How much plastic trash do you throw away per day?

Tiny bits of plastic rubbish ingested by marine worms are significantly harming to their health and will have wider impact on ocean ecosystems, scientists have found. Microplastic particles, measuring less than 5mm in size, have been accumulating in the oceans since the 1960s and are now the most abundant form of solid-waste pollution on Earth.

Ingestion of microplastics by species at the base of the food web is a cause for concern as little has been known about its effects until now. Microplastics can transfer harmful chemicals to marine life. This could include hydrocarbons, antimicrobials and flame retardants and many other chemicals that are found in plastics to the ecosystem. These could be passed on to humans through the seafood chain.

https://www.google.co.za/search?q=plastic+ingested+by+marine+worms&source=lnms&tbm=isch&sa=X&ei=SwwjU8HNKsuVhQes7ID4DQ&ved=0CAcQ_AUoAQ&biw=1024&bih=701

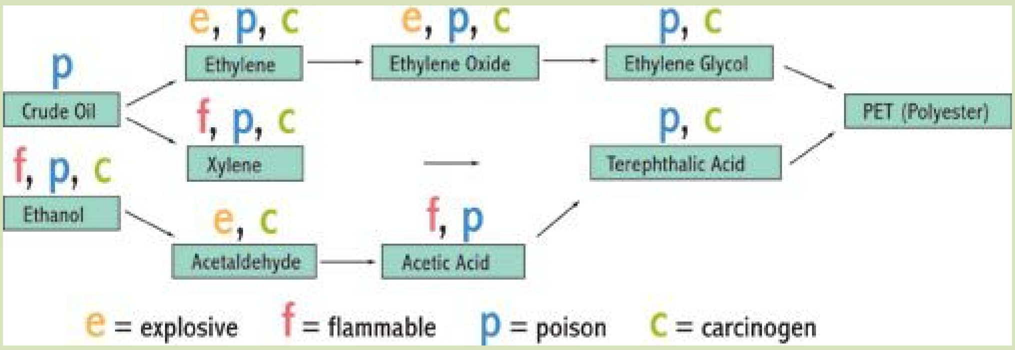
3.2 Health Alert- research more....this article has been downloaded from a blog

(discussion from Marc Pehkonen and Lori Taylor, writing in their website diaperpin.com:) – read it, do more research and make up your mind http://oecotextiles.wordpress.com/tag/monomers

(Check out the monomers that make up your clothes, jewelry, furniture, components etc)

Polymers are made by chemically reacting a lot of little molecules together to make one long molecule, like a string of beads. The little molecules are called monomers and the long molecules are called polymers.

Depending on which polymer is required, different monomers are chosen. Ethylene, the monomer for polyethylene, is obtained directly from the distillation of crude oil; other monomers have to be synthesized from more complex petroleum derivatives, and the path to these monomers can be several steps long. The path for polyester, which is made by reacting ethylene glycol and terephthalic acid, is shown below. Key properties of the intermediate materials are also shown.



The polymers themselves are theoretically quite unreactive and thereof and unreactive the polymers are, but that's not what we should be interested in. We need to ask, what about the monomers? How unreactive are they?

We need to ask these questions because a small proportion of the monomer will never be converted into polymer. It just gets trapped in between the polymer chains, like peas in spaghetti. Over time this unreacted monomer can escape, either by off-gassing into the atmosphere if the initial monomers were volatile, or by dissolving into water if the monomers were soluble. Because these monomers are so toxic, it takes very small quantities to be harmful to humans, so it is important to know about the monomers before you put the polymers next to your skin or in your home. Since your skin is usually moist, any water-borne monomers will find an easy route into your body.

Polyester is the terminal product in a chain of very reactive and toxic precursors. Most are carcinogens; all are poisonous. And even if none of these chemicals remain entrapped in the final polyester structure (which they most likely do), the manufacturing process requires workers and our environment to be exposed to some or all of the chemicals shown in the flowchart above. There is no doubt that the manufacture of polyester is an environmental and public health burden that we would be better off without.

What does all of that mean in terms of our health? Just by looking at one type of cancer, we can see how our lives are being changed by plastic use:

- The connection between plastic and breast cancer was first discovered in 1987 at Tufts Medical School in Boston by research scientists Dr. Ana Soto and Dr. Carlos Sonnenschein. In the midst of their experiments on cancer cell growth, endocrine-disrupting chemicals leached from plastic test tubes into the researcher's laboratory experiment, causing a rampant proliferation of breast cancer cells. Their findings were published in Environmental Health Perspectives (1991)[1].
- Spanish researchers, Fatima and Nicolas Olea, tested metal food cans that were lined with plastic. The cans were also found to be leaching hormone disrupting chemicals in 50% of the cans tested. The levels of contamination were twenty-seven times more than the amount a Stanford team reported was enough to make breast cancer cells proliferate. Reportedly, 85% of the food cans in the United States are lined with plastic. The Oleas reported their findings in Environmental Health Perspectives (1995).[2]
- Commentary published in Environmental Health Perspectives in April 2010 suggested that PET might yield endocrine disruptors under conditions of common use and recommended research on this topic. [3]

These studies support claims that plastics are simply not good for us – prior to 1940, breast cancer was relatively rare; today it affects 1 in 11 women. We're not saying that plastics alone are responsible for this increase, but to think that they don't contribute to it is, we think, willful denial. After all, gravity existed before Newton's father planted the apple tree and the world was just as round before Columbus was born.

Polyester fabric is soft, smooth, and supple – yet still a plastic. It contributes to our body burden in ways that we are just beginning to understand. And because polyester is highly flammable, it is often treated with a flame retardant, increasing the toxic load. So if you think that you've lived this long being exposed to these chemicals and haven't had a problem, remember that the human body can only withstand so much toxic load - and that the endocrine disrupting chemicals which don't seem to bother you may be affecting generations to come.

Again, this is a blog which is supposed to cover topics in textiles: polyester is by far the most popular fabric in the United States. Even if made of recycled yarns, the toxic monomers are still the building blocks of the fibers. And no mention is ever made of the processing chemicals used to dye and finish the polyester fabrics, which as we know contain some of the chemicals which are most damaging to human health.

Why does a specifier make the decision to use polyester – or another synthetic – when all the data points to this fiber as being detrimental to the health and well being of the occupants? Why is there not a concerted cry for safe processing chemicals at the very least? http://oecotextiles.wordpress.com/2011/10/13/polyester-and-our-health/

[1] http://www.bu-eh.org/uploads/Main/Soto%20EDs%20as%20Carcinogens.pdf

[2] http://ehp03.niehs.nih.gov/article/fetchArticle.action?articleURI=info:doi/10.1289/ehp.95103608

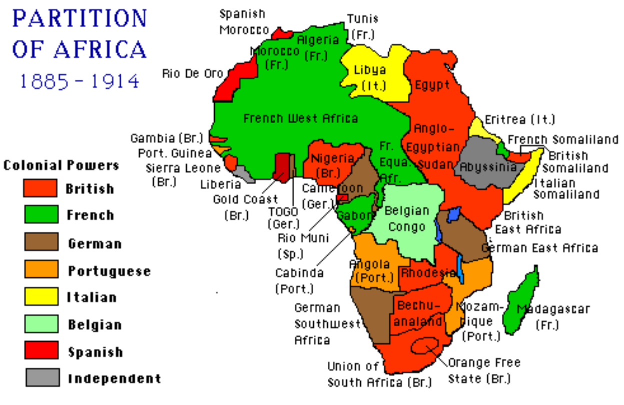
[3] Sax, Leonard, "Polyethylene Terephthalate may Yield Endocrine Disruptors", Environmental Health Perspectives, April 2010, 118 (4): 445-448

THE BACK PAGE: CONGO

The Story of polymers will be incomplete without the history of the barbarism of colonization and rubber exploitation by the French Speaking Belgians in the Congo

In scarcely half a generation during the late 1800s, in the European "scramble" for power and control of Africa; led to this continent, AFRICA, being sliced up like a cake with pieces going to Britain, France, Germany, Italy, Portugal and Belgium. Among them, they acquired 30 new colonies and 110 million subjects. In the process, the disruption of tribal life with separation of people into new tribal borders and nationalities was the order of the day. This resulted in the kind of *entangled* web of botched broken borders we have inherited from the colonial master and are made to believe this is who we are.

The carving of Africa by Europeans as they declared every bit of Africa as an extension of their European states during the voyages of expansion led to colonialism and the brutal conquest of Africans. The advent of the gun powder, initially a Chinese invention was soon turned into a weapon that was an important tool during the conquest and colonization of Africa. History says that before the advent of the gun, Africans had been involved in trade with countries across the seas in peaceful trade.



FOCUS OF THE DEMOCRATIC REPUBLIC OF CONGO (DRC)

Some fascinating facts about the Congo and the famous Congo River.

Patrice Lumumba was the first legally elected prime minister of the Democratic Republic of the Congo (DRC). He was assassinated on 17 January, 1961. Ludo De Witte, the Belgian author of the best book on this crime, qualifies it as "the most important assassination of the 20th century".

For 126 years, the US and Belgium have played key roles in shaping Congo's destiny. In April 1884, seven months before the Berlin Congress, the US became the first country in the world to recognize the claims of King Leopold II of the Belgians to the territories of the Congo Basin.

When the atrocities related to brutal economic exploitation in Leopold's Congo Free State resulted in millions of fatalities, the US joined other world powers to force Belgium to take over the country as a regular colony. And it was during the colonial period that the US acquired a strategic stake in the enormous natural wealth of the Congo, following its use of the uranium from Congolese mines to manufacture the first atomic weapons, the Hiroshima and Nagasaki bombs.

Patrice Lumumba was determined to achieve genuine independence and to have full control over Congo's resources in order to utilize them to improve the living conditions of the Congolese and freedom from exploitation. This resulted in his assassination.
http://www.theguardian.com/global-development/poverty-matters/2011/jan/17/patrice-lumumba-50th-anniversary-assassination

President Mobutu Sese Seko was the next president of Congo, followed by Laurent Desiré Kabila who has since been succeeded by his son, Joseph Kabila after his death.

The following are interesting facts about the Congo River; the Democratic Republic of Congo has been named after this river:

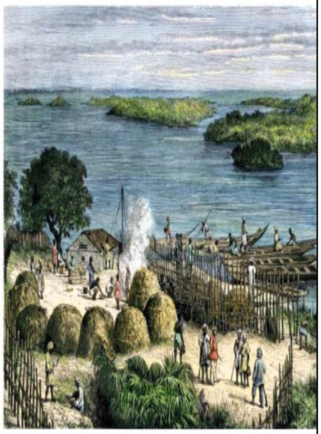
-
    - It is the second longest river in Africa (the Nile is the longest).
    - It is the ninth longest river in the world.
    - The Congo River is the deepest river in the world. It reaches depths of over 750 feet (230 meters).
    - The river gets its name from the ancient Kongo Kingdom which existed near the mouth of the river.
    - The river runs through the Congo rainforest which is the second largest rain forest in the world.
    - It was also called the Zaire River, during the reign of Mobutu
    - The Congo River’s sources are in the mountains and highlands of the East African Rift, as well as Lake Tanganyika and Lake Mweru.
    - The Congo River is so powerful that if has the potential to supply all of sub-Saharan Africa's electricity needs.
    - In 1482 Diego Cao was the first European known to sight and enter the Congo River.
    - The main tributaries are the Ubangi, Sangha, and Kasai.
    - There are more than 4,000 islands in the river; over fifty are at least ten miles long.
    - The river crosses the equator twice.
    - The river discharges a volume of water that is second only to the Amazon River.
    - Numerous cataracts (large or high waterfalls), dangerous rapids, and numerous islands make navigation difficult or impossible in certain areas of the river.

- Two countries are named after the river, they are The Democratic Republic of the Congo and the Republic of the Congo.
- The amount of water flowing out of the river is fairly constant year round due to the fact that some part of the river is always in a rainy season.
- Approximately seven hundred fish species have been recorded living in the Congo River. The total is probably much larger.
- The Congo River formed approximately 1.5 - 2 million years ago during the Pleistocene period.

  http://interesting-africa-facts.com/Africa-Landforms/Congo-River-Facts.html

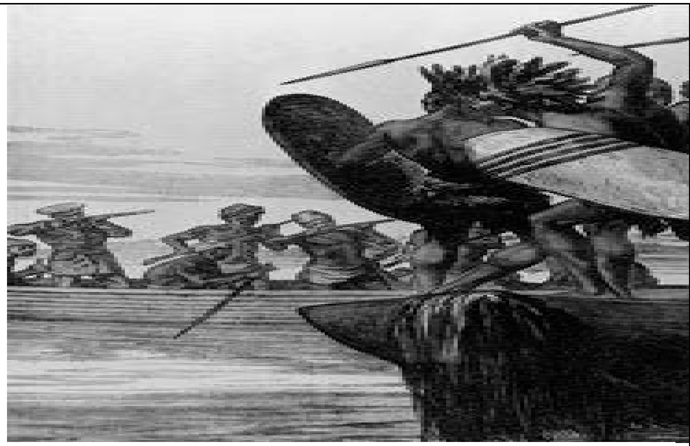
The Democratic Republic of the Congo is one of the world's richest countries in terms of natural resources. These include minerals (cobalt, copper, niobium, tantalum, industrial and gem diamonds, gold, silver, zinc, manganese, tin, uranium, coal) as well as petrol and timber. It is believed that 80% of the world's coltan is in DRC, and the overall underground reserves of its minerals have been estimated at 24 trillion of dollars.

The Democratic Republic of Congo (DR Congo) has the greatest extent of tropical rainforests in Africa, covering more than 100 million hectares. The forests in the eastern sector are amazingly diverse as one of the few forest areas in Africa to have survived the ice age. About 45 percent of DR Congo is covered by primary forest which provides a refuge for several large mammal species driven to extinction in other African countries. Overall, the country is known to have more than 11,000 species of plants, 450 mammals, 1,150 birds, 300 reptiles, and 200 amphibians. http://rainforests.mongabay.com/20zaire.htm

The Majestic Congo River	Pre-colonial Congo	Democratic Republic of Congo now
		

The story of the Democratic Republic of Congo

King Leopold II who ruled over Congo from Belgium without ever setting foot in the Congo



Although African rulers resisted, many battles were one-sided massacres *with Congolese armed with spears and the colonialists armed with guns and canons.*

A 1875 depiction of colonialists battling the native Congolese on the river *(Hulton Archive/Getty Images)*

PROCLAMATION

GHISLAIN.

The piece of paper that subjected generations of the people from the DRC to brutality Congolese - PROCLAMATION

I have the honor of informing the staff of the Independent State of Congo, to all the Congolese National that, as FROM THE 15 NOVEMBER 1908, the Belgium has assumed the sovereignty over the territories component the Independent State of Congo.

Bonna, on 16 November 1908,

for the General Vice-Governeur Absent,

the State's Inspector,

GUISLAIN

The face of colonialism

Such was the brutality of Leopold’s Congo that those who failed to meet the rubber quotas set by the Belgian officers, were routinely flogged with the chicote or had their hands severed (the chicotte was a whip made out of raw, sun-dried hippopotamus hide, cut into a long sharp-edged cork-screw strip. It was applied to bare buttocks, and left permanent scars. Twenty strokes of it sent victims into unconsciousness and a 100 or more strokes were often fatal. The chicotte was freely used by both Leopold's men and the French).

www.wordpress.com

BELOW: British missionaries with men holding hands severed from victims named Bolenge and Lingomo by A.B.I.R. militiamen, 1904.

http://www.allposters.com/-sp/African-Explorer-Henry-Stanley-s-Camp-on-the-Congo-River-c-1870-Posters_i2876152_.htmpre colonial Congo

Read more: http://digitaljournal.com/blog/11297#ixzz2ijwuAey4

Those who are conquered,' wrote the philosopher Ibn Khaldun in the 14th century, 'always want to imitate the conquerer in his main characteristics – his clothing, his crafts, and all his distinct traits and customs'.

The following is a story of brutality, oppression and the worst that human beings became, in the pursuit of rubber in the Congo.

King Leopold II of Belgium, like many other European rulers, declared Congo a colony of Belgium and set in motion a serried of events to first of all subdue and defeat the Congolese and finally to take out of Congo as much of the natural products of this country as possible, using the Congolese as laborers and each other's enemies. He eventually amassed a huge personal fortune by exploiting the Congo. The first economic focus of the colony was ivory, but this did not yield the expected levels of revenue. When the global demand for rubber exploded, attention shifted to the labor-intensive collection of sap from rubber plants. Abandoning the promises of the Berlin Conference in the late 1890s, the Free State government restricted foreign access and extorted forced labor from the natives. Abuses, especially in the rubber industry, included the effective enslavement of the native population, beatings, widespread killing, and frequent mutilation when the production quotas were not met. His army carried out their duties with extreme brutality on the Congolese.

The domainal system destroyed the traditional economy of the Congo basin and enforced a *labor tax* on Leopold's Congolese subjects requiring local chiefs to supply men to collect rubber and other resources. It essentially obliged natives to supply these products without payment. Genocide scholar Adam Jones comments, “The result was one of the most brutal and all-encompassing *corvée* institutions the world has known . . . Male rubber tappers and porters were mercilessly exploited and driven to death.” Leopold's agents held the wives and children of these men hostage until they returned with their rubber quota. Those who refused or failed to supply enough rubber often had their villages burned down, children murdered, and their hands cut off.

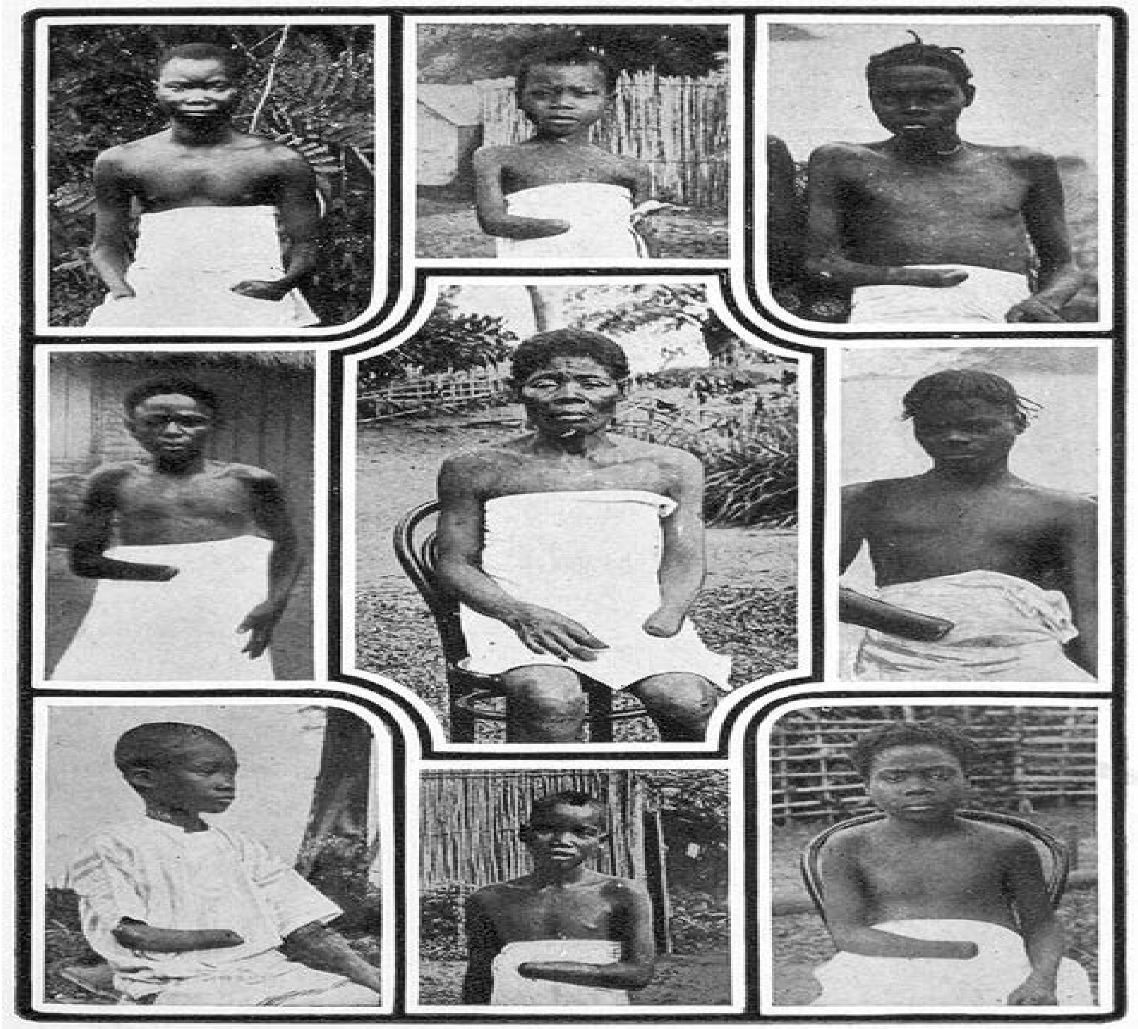
Local chiefs organized tribal resistance; rebellions often included Congolese fleeing their villages to hide in the wilderness, ambushing army units, and setting fire to rubber vine forests. In retribution, the army burned villages and soldiers went into the forest to find and kill hiding *rebels*. To prove the success of their patrols, these soldiers were ordered to cut off and bring back dead victims’ right hands as proof that they had not wasted their bullets. If their shots missed their targets or if they used cartridges on big game, soldiers would cut off the hands of the living and wounded to meet their quotas.

Although local chiefs organized tribal resistance, Leopold’s army brutally crushed these uprisings. Rebellions often included Congolese fleeing their villages to hide in the wilderness, ambushing army units, and setting fire to rubber vine forests. In retribution, the army officers burned villages and sent their soldiers into the forest to find and kill hiding rebels. To prove the success of their patrols, soldiers were ordered to cut off and bring back dead victims’ right hands as proof that they had not wasted their bullets. If their shots missed their targets or if they used cartridges on big game, soldiers would cut off the hands of the living and wounded to meet their quotas. After many years of war by the Congolese, the country was eventually granted independence.

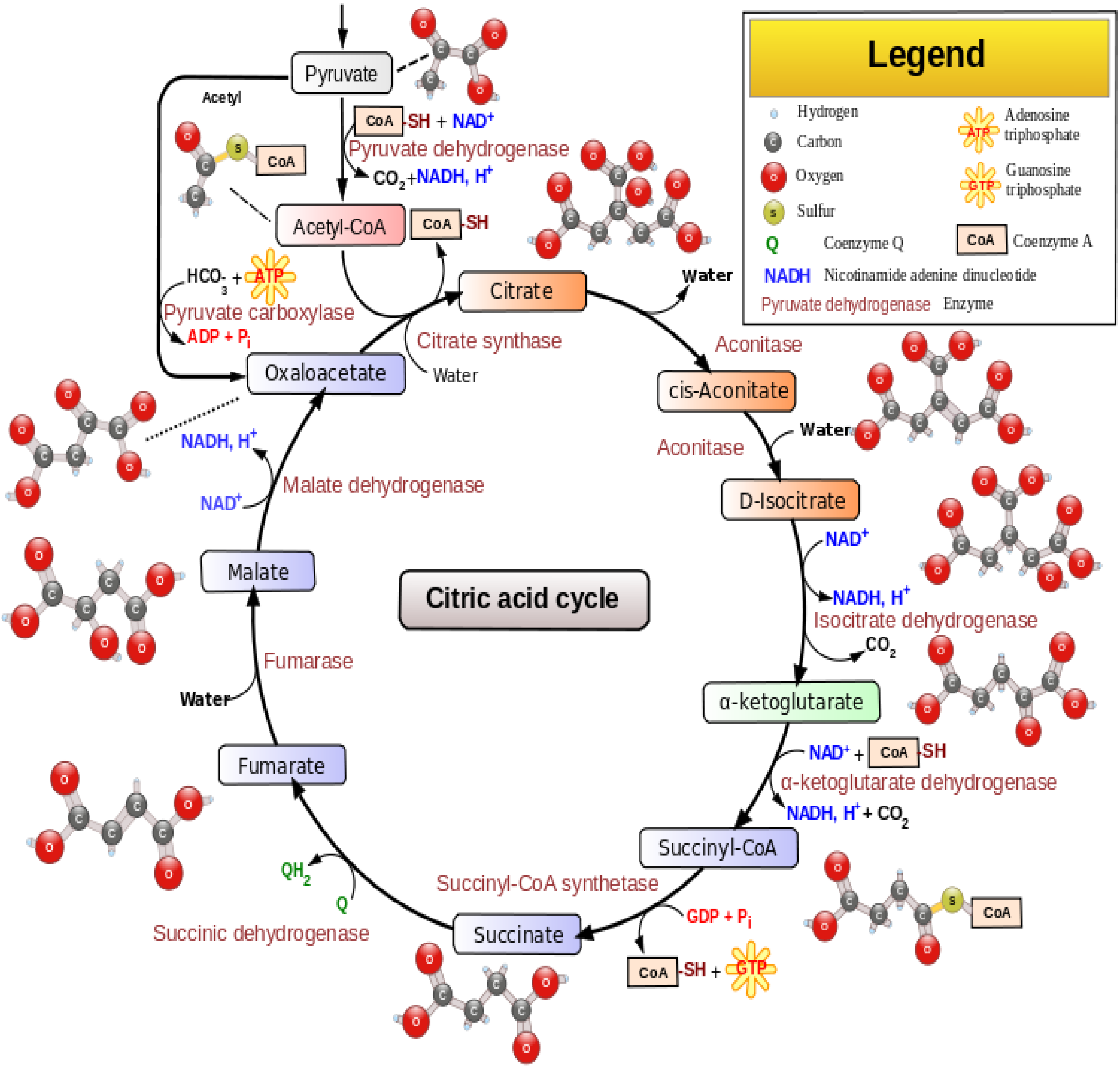
Such was the shame of brutality in colonial Congo. The rest as they say is history…

http://www.africanpeacejournal.com/everything-starts-somewhere/

An album of shame! Victims of the rubber trade in the Congo



http://www.africanpeacejournal.com/everything-starts-somewhere/


Legend
Hydrogen
Carbon
Oxygen
Sulfur
Q Coenzyme Q
NADH Nicotinamide adenine dinucleotide
Pyruvate dehydrogenase Enzyme
Adenosine triphosphate
Guanosine triphosphate
CoA Coenzyme A
Pyruvate
Acetyl
CoA-SH + NAD+
Pyruvate dehydrogenase
CO2+NADH, H+
Acetyl-CoA
CoA-SH
HCO3- + ATP
Pyruvate carboxylase
ADP + Pi
Citrate
Water
Citrate synthase
Water
Oxaloacetate
Aconitase
cis-Aconitate
Water
Aconitase
D-Isocitrate
NAD+
NADH, H+
Isocitrate dehydrogenase
CO2
α-ketoglutarate
NAD+ + CoA-SH
α-ketoglutarate dehydrogenase
NADH, H+ + CO2
Succinyl-CoA
Succinyl-CoA synthetase
GDP + Pi
CoA-SH + GTP
Succinate
Succinic dehydrogenase
QH2
Q
Fumarate
Water
Fumarase
Malate
NAD+
NADH, H+
Malate dehydrogenase
Citric acid cycle

Reference

https://www.google.co.za/search?q=plastic+soup+of+waste+floating+in+the+pacific+ocean&tbm=isch&tbo=u&source=univ&sa=X&ei=i__YUu-zJqaJ7AaB3oGgDw&ved=0CEkQsAQ&biw=1024&bih=725#facrc=_&imgdii=_&imgrc=G1xOVqGTB8zyVM%253A%3BWZ0_OrKizcAYxM%3Bhttp%253A%252F%252Fwww.funfactsgo.com%252Fwp-content%252Fuploads%252F2013%252F02%252FTrash-floating-on-the-Ocean.jpg%3Bhttp%253A%252F%252Fwww.funfactsgo.com%252Fearth-fun-facts%252Fthe-trash-floating-in-our-oceans%252F%3B400%3B264

http://1.bp.blogspot.com/_CTvgWqWUKUw/SwCJ5TGZyWI/AAAAAAAAAHI/Cd61HEySJ6E/s1600-h/Bird.jpg