CHAPTER P14 **PLEASE USE ONLY US ENGLISH; you must follow the format strictly; Browse through this sample chapter before typing yours in US ENGLISH only**

SYMPLOCOS PANICULATA **(SAPPHIRE BERRY): A WOODY AND ENERGY-EFFICIENT OIL PLANT**

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1. INTRODUCTION **all headings left justify**

Biofuel as an alternative to petro-diesel has received considerable attention due to diminishing availability of discoverable fossil fuel reserves and environmental consequences of exhaust gases from fossil fuels. The U.S. Energy Information Administration [29] has predicted that renewable energy except hydropower would account for 28% of the overall growth in electricity generation during 2012 to 2040. Biofuel is gaining popularity among the most important types of renewable energy, and the global demand for liquid biofuel has tripled between 2000 and 2007 [11]. Bioethanol is produced from agricultural feedstocks such as corn, miscanthus, sweet potato, sugar cane, sorghum, and switchgrass [7 , 26, 28], whereas biodiesel, alkyl esters of fatty acids, is made from edible animal fats and vegetable oils derived from coconut, linseed, palm seed, rapeseed, soybean, and sunflower [14]. A majority of biofuel feedstocks are food crops. As a consequence, biofuel feedstock production may compete in the long run with food supply and/or with food crops for arable land [14]. **= all citations must use numbering system**

Production of biofuel from edible oil is not feasible in China since there is a huge population of 1.35 billion and relatively inadequate arable land resources per capita. Oil bearing plants that produce non-edible oils in appreciable quantity and adapt to non-cropped marginal lands and wastelands would be better feedstock of choice for biofuel production. Fortunately, there are more than 4,000 species of plants in China with potential for bioenergy production [16]. A total of 38 oilseed crops have been identified as potential energy plants in China and are mainly distributed in tropical and subtropical areas [15]. *Symplocos paniculata* (Thunb.) Miq (sapphire berry or Asiatic sweet leaf) is one of the candidate bioenergy plants [16].

This chapter explores potential and adaptability of *Symplocos paniculata* (sapphire berry or Asiatic sweet leaf) cultivation for ornamental and medicinal uses, natural dyes production, and livestock feedstock. **= your chapter must have this paragraph**

2. NATURAL DISTRIBUTION AND MORPHOLOGY

Symplocos paniculata belongs to *Symplocaceae*. It is comprised of more than 300 species widely distributed in tropical and subtropical areas of the world. Among them, a total of 77 species are located in the mountainous regions of the eastern China [30]. Species in this family are usually found in the open area in the forest at an elevation of 100 to 1600 m. Along Daweishan Mountain (Liuyang, Hunan) from bottom to top, one can easily locate *S. chinensis*, *S. paniculata*, and *S. tanakana* [19]. Genetic analysis showed that the geographical elevation is greatly correlated with the genetic differentiation of *S. paniculata* [22].

Symplocos paniculata is widely distributed in Japan, Korea, Bhutan, India, Laos, Myanmar, and Vietnam [27] and most places in China [12]. It has a high adaptability to different temperature zones and varying soil conditions. It grows well in barren, salty, and severe drought soil like marginal land and hyper arid areas. Because of its developed root system with large active absorption root surface and high tolerance of disease and insect, this species plays an important role in maintaining ecosystem function and eliminating desertification and erosion [9]. In addition, *S. paniculata* is a national second level fire resistant species [34].

Symplocos paniculata is a deciduous shrub or small tree native to China with ecological and economic importance [21]. It typically grows one to five meters tall with spreading habit and taupe barks. The dark green leaves are ovate to obovate, finely toothed, and about three inches long (Fig. 1). It features two- to three- inch long panicles of creamy white, fragrant flowers in late spring followed by clusters of sapphire-blue berries (~1/3 long drupes) in fall. It usually blooms in April [33], and its fruits become mature at the end of September and early October [21].

A mature tree can yield up to 20 kg of fruit [32]. The whole fruit contains 36.6% oil [20], of which 79.8% is unsaturated fatty acid. Oil is mainly located in the pericarp of fruit (Fig. 2). Due to high fruit yield and oil content, *S. paniculata* serves as an ideal bio-diesel feedstock [18] and edible oil plant [10].

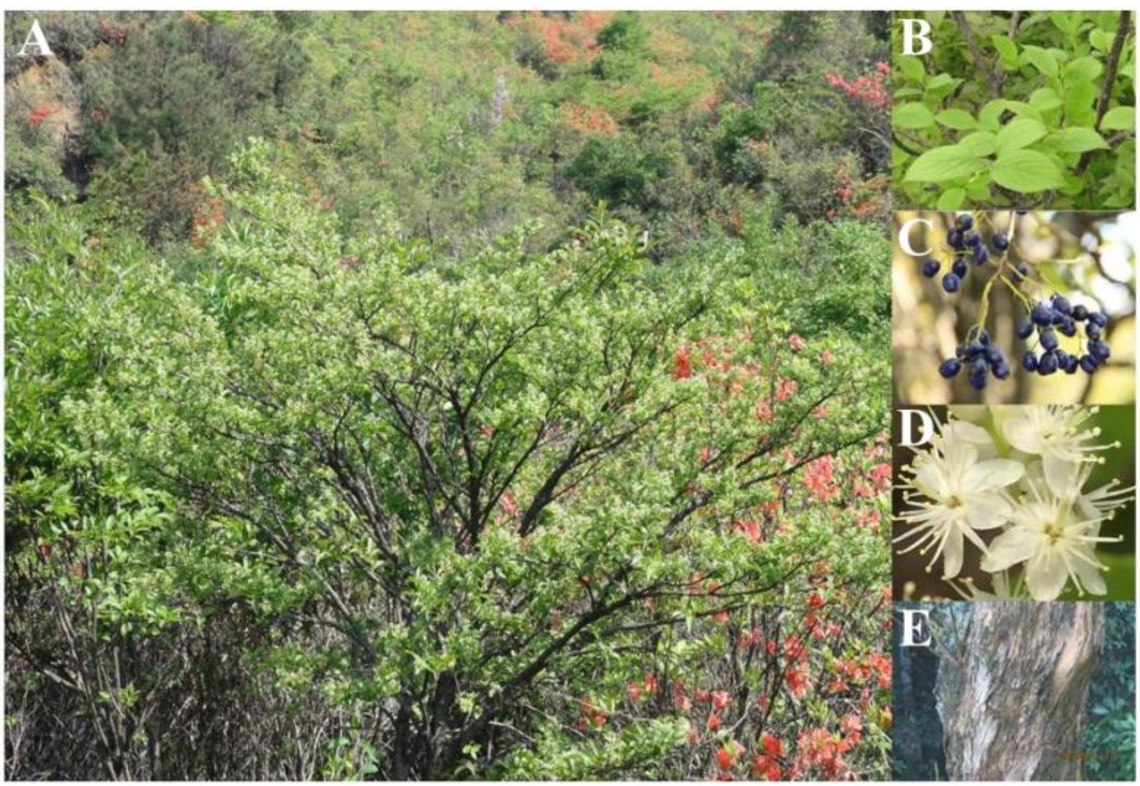

FIGURE 1 *Symplocos paniculata* tree grows in the wild (A), with green leaves (B), Sapphire-blue berries (C), white flowers (D), and taupe barks (E) **all headings for figs & tables left justify**

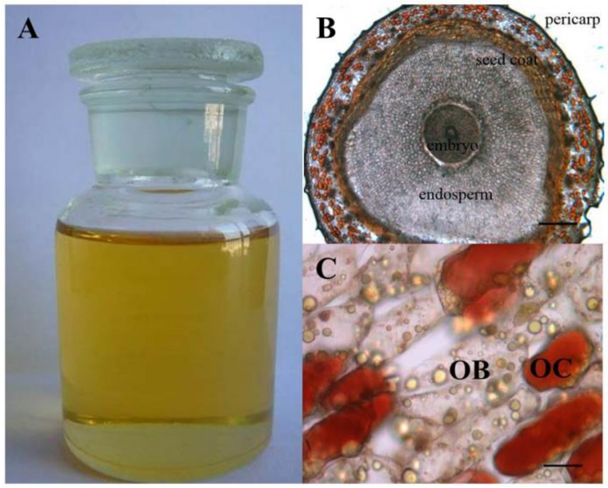

FIGURE 2 The oil produced from *Symplocos paniculata* fruit (A); transverse section of whole fruit (B, bar=1 mm) showing the spatial distribution of oil cells (OC); and oil bodies (OB) (C, bar = 10 µm).

3. USE OF *S. PANICULATA* OIL

3.1. Oil Extraction from *S. paniculata* Fruit

Owing to the high oil content and better fatty acid composition (Table 1), the fruit oil of *S. paniculata* is characterized as a potential source for cooking oil, biodiesel production, and other industrial uses such as ink surfactants, lubricants, and soap.

TABLE 1 Fatty Acid Composition of *Symplocos Paniculata* [20, 36] **must follow this format**

Components	Relative percentage (%)	
	Seed oil	Fruit oil
Palmitic acid (C16:0)	13.9	18.3
Stearic acid (C 18:0)	1.6	1.3
Oleic acid (C 18:1)	53.9	50.6
Linoleic acid (C 18:2)	31.8	26.7
Linolenic acid (C 18:3)	0.67	2.5

3.2. Cooking Oil

Symplocos paniculata has long been used as a cooking oil [10]. Zuo et al. [36] reported that oil extracted from *S. paniculata* seeds had high contents of oleic and linoleic acid and low contents of stearic acid. The transparency, smell and color of the oil produced from *S. paniculata* seeds are similar to that of ordinary cooking oil such as peanut oil (Table 2). But the acid value is higher than peanut oil, and Iodine value and saponification value are lower than peanut oil. Refinery processes are needed to improve the oil quality for use as cooking oil. Furthermore, a toxicity test was conducted by treating mice with *S. paniculata* oil at a moderate dose of 0.5~1 mL according to the maximum gastric volume (50 $mL \cdot kg^{-1}$), and no acute toxic symptom have been observed [36]. Increased motor activity, sedation, acute convulsion, coma and death were not found during the observation at regular intervals for 24 h up to 7 days [36].

TABLE 2 Physico-chemical Properties of Oil from Different Plant Species [17]

Oil plant species	Acid value	Iodine value	Saponification value	Refractive index
	mg KOH/g	g/100g	mg KOH/g	n_D (20)
Cornus wilsoniana	6.5	58.4	179.3	1.4849
Pistacia chinensis bunge	13.1	98.6	181.2	1.4728
Sapium sebiferum	2.2	124.9	144.5	1.4406
Styrax tonkinesis	0.8	75.8	165.5	1.5010
Symplocos paniculata	**18.6**	**71.9**	**152.2**	**1.4718**
Peanut	0.7	95.3	187.6	1.4720

3.3. Biodiesel Production

The physico-chemical properties are identification indexes of oil quality and they play a vital role in biodiesel production. The physico-chemical properties of several woody oil plant species have been identified in Table 2. Acid value is a measure of the amount of carboxylic acid groups in fatty acid. The acid value of *S. paniculata* oil is 18.59 milligrams of KOH per gram, which is higher than that of other oil plant species listed in the Table. The Iodine value is an index for the amount of unsaturation in fatty acids. The iodine value of *S. paniculata* oil is 71.93 grams per 100 grams, which is 25% lower than peanut oil. Saponification value is a measure of the average molecular weight (or chain length) of all the fatty acids present. *S. paniculata* oil has a saponification value of 152.22 milligrams of KOH per gram. It is comparable to *Sapium sebiferum* and *Styrax tonkinesis* oil and lower than peanut oil. Pretreatment processes are needed to improve the oil quality for biodiesel production; and the acid value of the *S. paniculata* oil should especially be reduced before transesterification.

3.3.1. Acid pretreatment

The crude oil of *S. paniculata* fruit has a high acid value, which may lead to low efficiency of biodiesel conversion. A pretreatment is required to reduce the acid value of the crude oil to an ideal range before transesterification. Liu et al. [18] conducted an experiment to de-acidify the crude oil produced from *S. paniculata* fruit. They mixed the crude oil with methanol at a ratio of

1:2 (W/V) and extracted at 32°C for 10 min, and this process was repeated 4 times. The acid value could be reduced from 18.59 milligram of KOH per gram to 1.5 milligram KOH per gram. The quality of oil was improved greatly and it was suitable for biodiesel conversion.

3.3.2. Fatty acid transesterification

Liu et al. [18] conducted experiments to convert the *S. paniculata* crude oil to biodiesel. *S. paniculata* crude oil was mixed with methanol at a molar ratio of 1:6 and catalyzed using NaOH at a dosage 1.2% by mass at 60 °C for 2 hours. The average transesterification rate was up to 92%. The biodiesel produced had a cetane number of 65.98, density of 0.892 g·cm^{-3}, and dynamic viscosity of 3.5 mm^{2}·s^{-1}. These measurements are similar to the 0＃ for petroleum diesel and qualify for European standard after bio-diesel conversion (Table 3). The flash point was more than 147°C, which is higher than 0＃ petroleum diesel (50°C). It is more potent in blending 20% biodiesel made from *S. paniculata* oil into petro-diesel.

TABLE 3 Comparison of Biodiesel Production from *Symplocos Paniculata* Fruit Oil with European Specifications and 0$^{\#}$ Fossil Diesel [18]

Property	**Biodiesel from *S. paniculata* fruit oil**	**European standard**	**0$^{\#}$ diesel**
Carbon residue	-	<0.3	<0.3
Cetane number (ISO 5165)	65.98	>51	46
Density (g·cm^{-3} at 20°C)	0.892	0.86-0.9	0.850
Flash point (°C)	147	>101	50
Sulphated ash	-	<0.02	0.25
Viscosity mm²/s at 40°C	3.5	3.5-5	2.7

4. ORNAMENTAL USES

Symplocos paniculata is a great potential ornamental plant with high quality in aesthetic appearance [23]. The plant has been introduced to the United States as a hardy ornamental for its beautiful creamy white, fragrant flowers, and sapphire-blue berries [1]. Along with the breeding and selection of *S. paniculata* for biodiesel production, two selections with distinguished sapphire berries have been developed and named as *S. paniculata* ‘Lan Jingling’ and ‘Zi Qiu’.

Symplocos paniculata ‘Lan Jingling’ is selected from a natural population at Daweishan National Park (Liuyang, Hunan) in China. A plant with sapphire blue fruits and acuminate leaves (Fig. 3A) distinguishes itself from other plants around. The population is distributed in the mountain area with an average elevation of 800 to 1600 m. Provenance test at the experimental plantation at the Hunan Academy of Forestry (Changsha, Hunan) showed that the unique features could be maintained stable and plants can reach three meters tall in five years with a fruit yield of 2.5 kg per tree. It blooms from May to June.

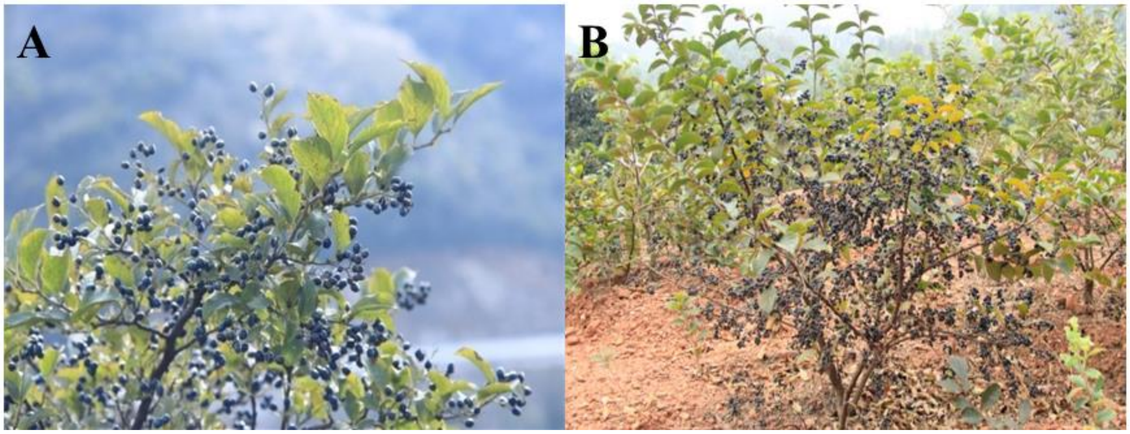

FIGURE 3 Two newly selected *Symplocos paniculata* cultivars (A: 'Lan Jingling'; B: 'Zi Qiu') for ornamental uses.

Symplocos paniculata 'Zi Qiu' is selected from a pool of clones with high fruit yield at the experimental plantation at the Hunan Academy of Forestry (Changsha, Hunan). The clones are propagated from a plant in the natural population at an elevation of 100-450 m. It is a natural dwarf shrub with a vigorous branching habit. The flowering period is usually from April to May, one month earlier than *S. paniculata* 'LanJingling'. The unique features are grey fruits and acute leaves (Fig. 3B).

However, the exploitation of *S. paniculata* for ornamental uses is still limited. More research is needed to breed and select novel cultivars, test their genetic stability and adaptability, and to develop commercial propagation protocols.

Symplocos paniculata is an ideal plant for bonsai because it grows extremely slow [35]. The special shape and delicate texture of *S. paniculata* roots make it an excellent candidate for root carving [25]. In addition, *S. paniculata* produces a delicate texture of timber, which is ranked one of the finest woods in China. The timber can be processed for upscale furniture, cabinet work, decorative objects, woodcarving, musical instruments, precision molds, religious artifacts, etc.

5. MEDICINAL VALUE

Symplocos paniculata has long been used as a traditional herbal medicine in China. Its roots and leaves have pathogenic heat expelling, detoxifying, detumescence and anti-inflammatory effects that make it useful in treating mastitis, lymphadenitis, enterodynia, gastric cancer, boils, skin itching, hernia and urticarial [31]. The flowers can be used to treat fever, stomachache, nausea, vomiting, diarrhea, and burn [31]. The bark has astringent, cooling and tonic effects, which are useful in the treatment of menorrhagia, bowel complaints, eye diseases and ulcers [6]. The phytochemicals from stem bark of *S. paniculata* have antimicrobial, analgesic, and anti-inflammatory activities and have been used as traditional medicine for checking abortion in India [27]. Protein Tyrosine Phosphatase-1B (PTP1B) was also extracted from leaves and stems of this species and proposed as a therapy for the treatment of type 2 diabetes and obesity [24].

6. NATURAL DYES

Natural dyes originated from plant materials are a sustainable source of colorants. In contrast to the hazardous effects of synthetic dyes on skin such as allergy, skin cancer, etching, rashes, etc. [13] and severe water and atmospheric pollution resulting from non-degradable byproducts, natural dyes are non-toxic, biodegradable, and ecologically safe. To meet the demand of green chemistry and the use of safer chemicals to minimize the pollution for environmental considerations, the cultivation of dye plants and the development of novel natural dyes have recently drawn considerable attentions. A yellow dye is obtained from its rough yellowish-brown and corky bark [8]. Badoni and Semwal [2] conducted a study to apply the dye extracted from *S. paniculata* leaves and bark on white cotton thread and cloth, particularly to compare the affinity of vegetable mordents (*Euomymus tingens* bark extracts and *Myrica esculenta* leaf extracts) and common synthetic mordents (copper sulphate and stannous chloride) with fiber. They concluded that *S. paniculata* (leaves and bark) dyed with natural mordents (extracts *from Euomymus tingens* bark extracts and *Myrica esculenta* leaf) produce different color hues with better fastness properties than that of synthetic mordents ($CuSO_4 \cdot 5H_2O$ and $SnCl_2 \cdot 2H_2O$).

Natural dyes have been also used in food industry as safe food additives, in cosmetics, and in pharmaceutical preparations. Chen et al. [4] reported that *S. paniculata* fruits contain abundant red pigment (605 mg/100g), which can be easily extracted with organic solvent of 50% ethanol and 1.5 mol/L HCl at a volume ratio of 15:85. They further optimize the extraction technique of total flavonoids of *S. paniculata* leaves and found that 4.6 % yield of total flavonoids could be extracted using 60% ethanol with application of ultrasonic wave (25 KHz) for 50 min at 80℃ [3]. The produced red pigment was identified as water-soluble and alcohol-soluble anthocyanins with high stability in acid solution, in solution containing Na_2SO_3, K^+, Ca^{2+}, Na^+, Mg^{2+}, Al^{3+}, or Zn^{2+}, and under light or heat [5]. High content of glucose maltose citric acid can protect color of the pigment, while H_2O_2, Vitamin C, Cu^{2+}, Mn^{2+}, Fe^{3+} and high content of sorbic acid can degrade the pigment.

7. LIVESTOCK FEED

Symplocos paniculata contains 12.8%-13.9% of crude protein and 16.4% of crude fiber in fresh leaves. Seed cake, a byproduct obtained from oil extraction, is also high in protein. In both fresh leaves and seed cake, there are 17 kinds of amino acids such as lysine, methionine, threonine, isoleucine, glutamic acid, alanine, and arginine (Table 4). Among them, seven kinds are essential amino acids for animals, for example: lysine, phenylalanine, methionine, threonine, isoleucine, leucine and valine. Please note there are only nine kinds of amino acids in rice hull and 10 kinds of amino acids in wheat hull and bean cake. The content of the amino acids in fresh leaves and seed cake of *S. paniculata* is comparable to or higher than that in rice hull, wheat hull, and bean cake (Table 4). In addition, they are also rich in vitamin C (Table 4) and minerals (Table 5) in both the leaves and seed cake of *S. paniculata*. Therefore, the leaves and seed cake would be a valuable livestock protein feed supplement.

TABLE 4 Amino Acids and Vitamin C Content in Leaves and Seed Cake of *Symplocos Paniculata* and Comparison with Other Byproducts for Feedstock Use [10, 36]

Parameter	*Symplocos paniculata*		Rice hull mg/100g	Wheat hull mg/100g	Bean cake mg/100g
	Leaves mg/100g	Seed cake mg/100g			
Alanine (Ala)	0.83	0.31	-	-	2.30
Arginine (Arg)	0.83	1.02	1.00	0.98	1.10
Aspartic acid (Asp)	1.41	0.56	-	-	-
Cysteine (Cys)	0.23	0.05	0.09	0.1	2.80
Glutamate (Glu)	2.06	1.30	-	-	-
Glycine (Gly)	0.75	0.29	1.00	0.66	-
Histidine (His)	0.31	0.14	0.3	-	-
Isoleucine (Ile)	0.67	0.26	0.40	0.39	3.80
Leucine (Leu)	1.24	0.53	-	0.69	2.20
Lysine (Lys)	0.74	0.23	0.5	0.65	-
Methionine (Met)	0.16	0.08	0.02	0.08	2.70
Phenylalanine (Phe)	0.71	0.26	0.40	0.36	2.80
Proline (Pro)	0.68	0.22	-	-	0.62
Serine (Ser)	0.70	0.31	-	-	0.60
Threonine (Thr)	0.62	0.23	0.4	0.39	

Tyrosine (Tyr)	0.48	0.17	-	-	2.10
Valine (Val)	0.79	0.33	-	0.56	-
Vitamin C	22.36	3.44	-	-	

TABLE 5 Mineral Contents in *Symplocos Paniculata* Seed Cake [36]

Minerals	K	Ca	Mg	Fe	Na	P	Zn	Ni	Cu	Mn
Content ($mg \cdot kg^{-1}$)	4231	7686	928.4	195.2	56.18	1509	11.92	4.31	7.4	120.2

8. SUMMARY = this section is a must

Sympolocos paniculata is a new energy-efficient plant with superior adaptability and ecological benefits. As awareness among people towards eco-friendly natural products increases, it shows great potential for use in biodiesel production. Research activities on the production of biodiesel from the fruit oil are summarized. This chapter also documents the treasures of indigenous knowledge of other multiple uses such as ornamental and medicinal uses, natural dyes production, and livestock feedstock. More detailed research is needed to assess the real potential and availability of this renewable plant species and to optimize production procedures to improve the quality and quantity of biodiesel. Biotechnology and other modern techniques are required to breed better cultivars with high fruit yield and oil content, to develop a rapid propagation protocol to produce this high-demanding species on a commercial scale, and to cultivate this species for biodiesel production and other industrial uses.

ACKNOWLEDGEMENTS = optional

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KEYWORDS add here words>25; we use it for subject index…..

Biodiesel

Byproduct

Cooking oil

Medicinal value

Natural dyes

Oil

Ornamental uses

Renewable energy

Symplocos paniculata

REFERENCES

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APPENDIX – A **= add here all appendices for the chapter if any**

APPENDIX – B

Glossary of Technical Terms

please define here >10 terms used in the book, in the alphabetical order. Use the format given below……;; you may use google search to find the definitions

Alternating current is a form of electric current in which the movement of electric charge periodically reverses direction.

LIST OF ABBREVIATIONS IN THIS CHAPTER = this section is a must in the alphabetical order

OC	oil cells
PTP1B	Protein Tyrosine Phosphatase-1B