Lab # 9. Tourmaline, Quartz (including opal), Chrysoberyl, Zircon. Crystal shapes, distinctive properties.

Tourmaline, quartz, zircon, and opal are silicates. They have silicon and oxygen atoms as there backbone. The mineral chrysoberyl is a beryllium oxide of aluminum, of the same basic chemistry as ruby and sapphire plus the element beryllium. The reason for lumping these minerals is more their economy, they are fairly popular, than their similarity. That is their values and demand overlap.

Tourmaline certainly can make very spectacular and valuable mineral specimens. As a gem it is usually less expensive than chrysoberyl and good quality opal, but more valuable than quartz and most zircon. Quartz is the least valuable as a gemstone, but may in fine natural specimens of crystals, obtain high prices are the size and color/quality of the crystals increase or intensify. Opal may also occasionally be used as a decorative mineral, but is rarer than tourmaline or quartz. Generally chrysoberyl and zircon do not make impressive mineral sample specimens.

**QUARTZ.**

We will start with quartz, because it is a very abundant mineral on earth. It is in the silicate group; it is only surpassed by feldspar mineral in abundance. Quartz is so abundant, that **its hardness 7** is critical. It becomes a **gatekeeper** by the very fact that there is so much quartz in dust and sand that it is always around to **scratch any stones of inferior hardness**.

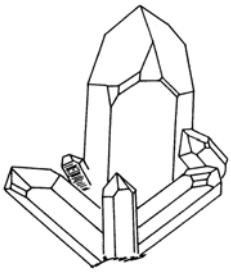
Anything that is harder than quartz is considered a **potential ringstone**, though some who consider such things have suggested that tourmaline (up to 7.5) is a little soft for a ring. Most experts doubt this! Though you will still find this in print.

Quartz forms hexagonal crystals, it is in the trigonal crystal system, according to the online database of minerals, Mindat.org

> Quartz is the most common mineral found on the surface of the Earth. A significant component of many igneous, metamorphic and sedimentary rocks, this natural form of silicon dioxide is found in an impressive range of varieties and colours(sic). There are many names for different varieties: Cryptocrystalline varieties of quartz are listed separately under chalcedony, and include agate.

We will only discuss the crystalline transparent type here, cryptocrystalline (microscopic crystals) varieties are import in cheaper jewelry and in mineral specimens, but not for our investigations.

Figure 1, below, shows a quartz crystal cluster, striations grow at 90$^{o}$ to the length on one of the small crystals. Mostly these would all have striations. As they grow from a common point they form a cluster.



One small crystal has visible striations. The tips of the crystals are called the terminations. The flat surfaces due to growth are the crystal faces. Most quartz crystals are six sided and elongated, their color creates the following varieties in Table 1.

Table 1 Colors of Quartz

| Variety | Amethyst | Crystal | Citrine | Smokey | Greened | Rose |
|---|---|---|---|---|---|---|
| | Purple | Colorless | Yellow-orange | Gray-black | Green | Pink |

Any of these could be made in the lab by hydrothermal growth and treatment (perhaps not rose). Natural amethyst can be heated to make it either green or citrine (some geodes are broken in half and heated and turned half orange). Rose quartz is usually not completely transparent.

Quartz makes lovely cut stones; cabochons and facet stones may be of equal quality since it is not a rare gem. It is fairly high tenacity, and is found in many types of rock, depending on geographic locality most indigenous people have a variety of quartz that is popular. It is also carved, as in the famous crystal skulls of Central America and many other lovely objects. During the "stoneage" flint and chert, cryptocrystalline varieties were very important for tool making.

**Unusual Varieties and properties of Quartz**

These are sometimes referred to as "**phenomenal properties**." More about this under Chrysoberyl.

**Cat's eye** quartz exists. Discussed more under Chrysoberyl.

**Tiger's eye** quartz is a replacement of a fibrous type of asbestos called "crocidolite." According to Mindat.org, "Tiger's-eye is an attractive and popular gemstone that is ubiquitous in stores that cater to rock and mineral collectors. For more than a century, textbooks and museum displays have identified the material as an archetype of **pseudomorphism**, i.e., the replacement of one mineral by another with the retention of the earlier mineral's shape." There seems to be some recent controversy about this, but we will assume the fibers in cat's eye are due to asbestos replacement and are pseudomorphs.

Piezoelectric effect. If quartz is put under pressure, electrons move to the "points" of the crystal and a spark may jump, as happens with some "flintless" cigarette lighters. Quartz is used in watches because of the piezoelectric effect. If you apply an electric current, the quartz will contract and expand, just the opposite of crushing it! Thus you run a current, the quartz wiggles, and it keeps time. This is used in quartz watches. Quartz also has uses in radios and other electronics.

Hydrothermal Quartz. Hydrothermal quartz is grown from a seed. We will observe the seed and the unusual "orange peel" like growth on a crystal's surface.

Rutilated Quartz. Rutile (golden to red) and tourmaline (black, green, blue) often form long needs in quartz. Sometimes the rutile , if microscopic, can make **star quartz**. We will look at a mirrored back quartz made with a blue foiled back to simulate a star sapphire.

**TOURMALINE**.

Tourmaline is borosilicate. Boron, element 5 on the periodic table is rare. But tourmaline is found in all types of rocks just as quartz is, but in much smaller amounts. It is rarer and more valuable in gem types.

Tourmaline is a little more brittle than quartz, and though it is harder some jewelers have argued it is not a good ringstone. This is probably wrong. Besides being cabochoned (usually inferior material) and

faceted (usually higher quality material), it is often carved. The Chinese bought much tourmaline from San Diego for carving into snuff bottles around the beginning of the last century.

Tourmaline of a very rich red resembles ruby, hence rubellite. There are also several varieties of tourmaline based on chemical composition. Most but not all gem tourmaline is in the "Elbaite" family

The three commonest varieties are described in Table 2. You should know that elbaite is the main gem variety.

Table 2 Common Varieties of Tourmaline

| Variety | Schorl | Dravite | Elbaite |
|---|---|---|---|
| General Chemistry | $NaMg_3(Al,Mg)_6B_3Si_6O_{27}(OH)$ | $NaMg_3Al_6Si_6O_{18}(BO_3)_3(OH)_4$ | $Na(Li_{1.5},Al_{1.5})Al_6Si_6O_{18}(BO_3)_3(OH)_4$ |
| Color | black | brown | Roygbiv* (any color possible) |

* Roygbiv. We are here saying almost any color of the rainbow, also achroite (colorless), and color zoned.

Certainly you do not need to know the tourmaline variety formulas, but they are quite complex for silicates; this you should know. There are a lot of other varieties of tourmaline, some of gem significance, but for now these three varieties are enough.

Tourmaline forms elongated, six-sided crystals that often have curved sides that form a shield like shape (Figure 2.) Striations are found on crystal faces parallel to the long axis.

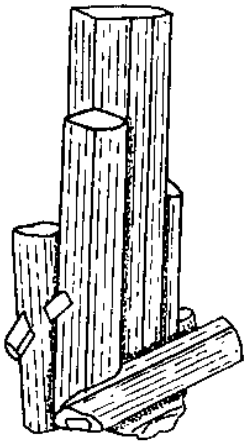


**Figure 2. Tourmaline crystals with lengthwise striations.**

The huge variety of colors, literally a rainbow of colors, makes tourmaline a collector's stone. Tourmaline is often color zoned, both internally and lengthwise. The zoning is very geometric and can be sharp or gradational. Blue cap tourmaline used to be considered a San Diego specialty, but new discoveries of tourmaline in the Himalayas of Afghanistan and Pakistan have similar colors.

The best tourmalines are either alluvial or from pegmatites. Most of the gem alluvial tourmaline started in pegmatities.

**Unusual Varieties and properties of Tourmaline.**

One of the unusual properties of tourmaline is it has very strong absorption of light. This is **related with the two directions (parallel and 90$^o$ )** to crystal length. As you will see, when you look down a crystal's length (page *) the light and color looks different than across the crystal. You could see this with a dichroscope, but you do not need one with tourmaline.

Cat's eye tourmaline. Strikingly colorful varieties, pink, blue, green can have the cat's eye effect. Large stones are possible. Probably larger than any other gem mineral in this category.

Piezoelectric effect. As with quartz if tourmaline is put under pressure, electrons move to the "points" of the crystal and a spark may jump, as happens with some "flintless" cigarette lighters. Tourmaline also becomes charged if warmed slightly, as for example, sunlight shines on a tourmaline in a jeweler's case. When "charged" with an electric field or heating, tourmaline attracts dust and ash, or small pieces of paper. According to the *Wikipedia.org* site on tourmaline, tourmaline is from "Sinhalese word **turamali**, meaning "stone attracting ash" (a reference to its pyroelectric properties)." Pyroelectric means "heat electric" and is similar to piezoelectric as discussed above.

CHRYSOBERYL.

Chrysoberyl is a beryllium aluminate, unlike the other gemstones mentioned so far, it does not contain silica. It is rarer than the other minerals mentioned, but not so rare as a fine ruby, emerald, or diamond. There is one exception; a variety colored with chromium does a **change of color depending on light**. This variety, alexandrite, is **red** in regular room light (incandescent bulb) but is **green** in a more full spectrum fluorescent bulb or sunlight. The red green color change can be very dramatic. These special chrysoberyls, found in Russia (Ural Mountains), Sri Lanka, Brazil, Madagascar, and India (based on importance of deposits) **demand extremely high prices**. This depends a little on the two colors which at best can be emerald green and ruby red, but can be much more muted in less expensive color change stones.

Beware! Most jeweler's have not seen a true color change alexandrite; they have seen synthetic color change sapphire made by the flame fusion process. This material is not similar in color, being much more purple. Some synthetic spinel is supposedly a better fake.

Other chrysoberyl, besides the infamous alexandrite, named after Czar Alexander II of Russia ( 1818 - 1881), are usually a green to green-yellow and can be very pleasing. Chrysoberyl is very hard, **8.5 on Mohs scale** and very tenacious. It makes a good ringstone.

Cat's eye chrysoberyl is the most important type of cat's eye (it does not need to have anything written after it according to the FTC "Cat's eye" alone is always chrysoberyl. Cat's eye chrysoberyl is also called Cymophane. Cymophane means from the cat's eye variety of chrysoberyl. The property of having a cat's eye is also called displaying "Chatoyancy." Chatoyancy is the French word for cat's eye.

Any gemstone can be chatoyant, but only chrysoberyl cat's eye can be cymophane.

**How Chatoyancy Works**

Different minerals may have a cat's eye effect, a very bright line of light that crosses a well cut cabochon. Apparently, chrysoberyl has the best, strongest, and sharpest line, often it is slightly blue. What forms it is light hitting an object with parallel lines, these lines can be hollow tubes, fibrous mineral inclusions (tiger's eye), or even parallel scratches made by a jeweler (or lapidary) on the back of a stone. The bright line forms as a result at $90^{o}$ or a right angle to the parallel lines (fibers or cavities in the gem). It is not that uncommon and varies in cause in different gems, cavities or included fibers. Metal appliances like refrigerators with a parallel brushed metal finish and grained wood on polished furniture, can also show this line or chatoyancy. The line looks best in 1) sunlight or 2) a flashlight with a strong beam. The stone, when not in the sun or with a penlight flashlight shining on it will not show

chatoyancy. So some people are not impressed. But it is an unusual phenomenon, and if a good stone cutter does a good job on a fine cat's eye, it will be a beautiful effect that is very eye catching.

Also cat's eyes may show color variations along the stone. One type of cymophane is called "milk and honey" as one side is darker honey brown and other side appears lighter like milk. Some cymophane is also alexandrite and shows a color change.

Opal.

Precious opal shows play of color. Other opal exists that may have a banded (agate-like) appearance or pleasing color, but only precious opal demands a high price and is discussed in detail here. The cause of play of color is diffractions from spheres of opal in the range of a few microns (millionths of a meter) in diameter. These sphere act like a CD-ROM or DVD with very fine lines (also a diffraction grating made for spectroscopes), they break up light into spectral colors (Roygbiv).

Precious opal, as with common opal, is hydrated silicon dioxide ($Si_2O \cdot nH_2O$). The n in the formula is because the amount of water is variable. So opal **dehydrates and cracks**. Cracking of opal is called **crazing**. It was thought to be a sign of bad luck and some people thought opal to be unlucky. Opal may crack after a few years out of the water. Many good jewelers hold their opal to test this. Opal is also soft, 5-6.5 mohs hardness and brittle**. So it is not a good ringstone!**

Most Nevada opal crazes. The best opals, in general, come from Australia. The most pricey is black opal. Black opal is a rare and **has a dark blue background**, against which the play of the other color is most dramatic demanding highest prices. The more red, in a black opal, generally the better.

Often doublets and triplets are made of thin bits of opal. The thinness is protected by a glued backing making a **composite doublet**. Having a top of colorless glass or quartz protecting the thin slice makes a **triplet**, along with the backing. For obvious reasons, the backing is often black. However, some fakes exist. Here a thin slice is glued to a opal backing by an expert to make it look solid, rather than just supported. This solid opal is worth much more than a doublet. So **caveat emptor** (let the buy beware!)!

Besides, solid, doublet, and triplet opals, there is one other type called **boulder opal**. Opal deposited from water seeping between cracks creates boulder opal. It can be black or white opal, but is only a thin natural veneer. The boulder opal often is between dark brown ironstone (a cement like rock of rusty iron like materials) and is cut leaving a backing of this ironstone.

There are generally **3 grades of precious opal color**, **black** mentioned above, **white** (which can be milky to literally a porcelaineous white background) with play of color, and **fire** (which is red to yellow often with reduced or no play of color). Jelly opal can be colorless with play of color. **Potch opal** means nothing nice about it at all. Just white or gray opal. As mentioned most precious opal is from Australia, some comes from Brazil (recently black opal), Nevada, Ethiopia (a source of recent high quality [though some crazes] opal), and Indonesia. Much fire opal comes from Mexico. Ancient opal used by the Romans and others in Europe came from Romania.

**Sugared opal**. Sometimes bad opal is treated with sugar and acid this dyes the opal background black and creates a more pleasing background similar to black opal. The opal must be porous, as described below to absorb the sugar water before acid treatment. This is called sugared opal or smoked opal.

OPAL PHENOMENA.

Opal can have chatoyancy (cat's eye) like the other gems. Chatoyant opal may not have play of color and would probably go unnoticed if it did.

Opal can absorb water. This property is called **hydrophane** when it makes the opal transparent. The water can go in and displace air between the spheres of silica so fast you can hear it fizz! Bubbles may be visible similar to Alka-Seltzer tm. fizzing. **Contraluz** opal when wet gets play of color. It apparently is dull without it. The play of color is seen looking through the opal.

Opal can act like a diffraction grating and may show a full spectrum along the stone. This is unusual.

There are also opal **pseudomorphs**, "pseudo" means fake or in this case, it replaces something. Fossils are sometimes replaced by precious opal. Clams or other seashell may be replaced, as well a famous swimming reptile from the age of dinosaurs called a plesiosaur that had many of its bones replaced by opal in Australia. Another thing that is replaced by opal are ooids round calcium carbonate concretions that make the rook oolite. We have an example of sugared opal with ooid pseudomorphs (p. 17).

Zircon.

Zircon is composed of zirconium silicate ($ZrSiO_4$), often it is an off brown, red or green color. Mostly zircons are heated. On heating some becomes colorless, others become blue, etc. Unheated zircon undergoes both color and clarity changes on heating.

Most zircon, called high zircon, has strong double refraction, like calcite. That is it doubles things viewed through it, but zircons are small. One way to see doubling is through the microscope or loupe, the back facets appear twice. This is called **facet doubling**. Many gemstones do this a little, but zircon does it very strongly.

However, high zircon does double, but two other types of zircon exist, a mixed level (called medium) that has intermediate properties, and a "low zircon." Low zircon does not double the facets. It is not behaving correctly! Why? It has suffered **radiation damage** that has destroyed its internal atomic arrangement of atoms. This is also known as **Metamict zircon**. Since there is no crystal structure, light is not broken into two beams of light that vibrate at right angles to each other and thus there is no doubling of the facets!

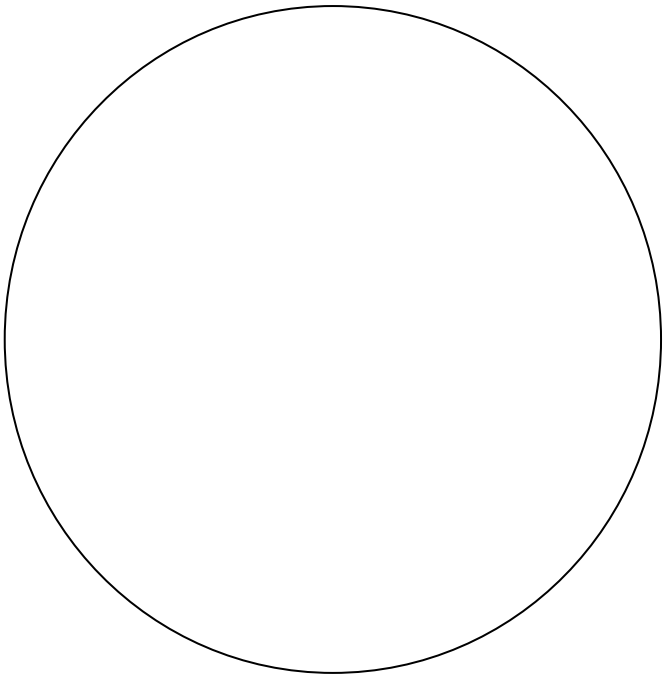
Zircon does not have so much radiation that you should worry, but it might be best not to store it close to you for prolonged periods of time. Since at least some zircon is slightly radioactive.

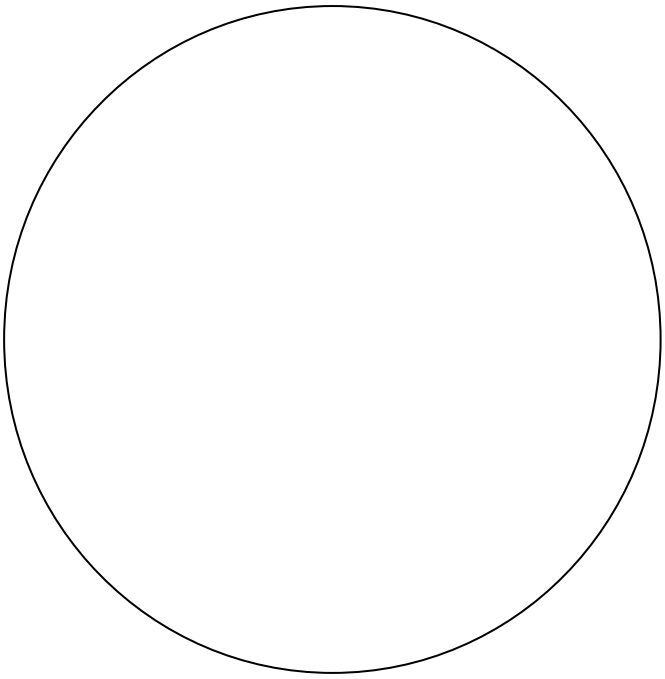
Interestingly, low zircon can be restored to high zircon by heating that reverses the radiation damage if done correctly! Hence heating does more than change the color and clarity, it also **restores the atomic structure**!

ZIRCON PHENOMENA.

Doubling of things is the main phenomenon shown by zircon. However, sometimes it occurs as a cat's eye (chatoyant stone) too. Also interesting as you go from high to low zircon, the specific gravity decreases. Apparently radiation damaged zircon expands! This may explain zircon haloes in sapphires!

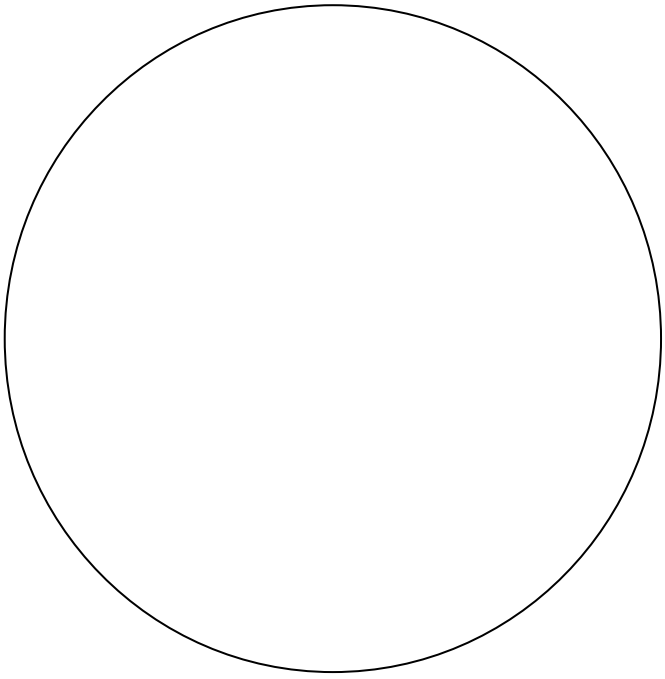
Quartz A) Draw a whole crystal. Look on the crystal face and draw striations

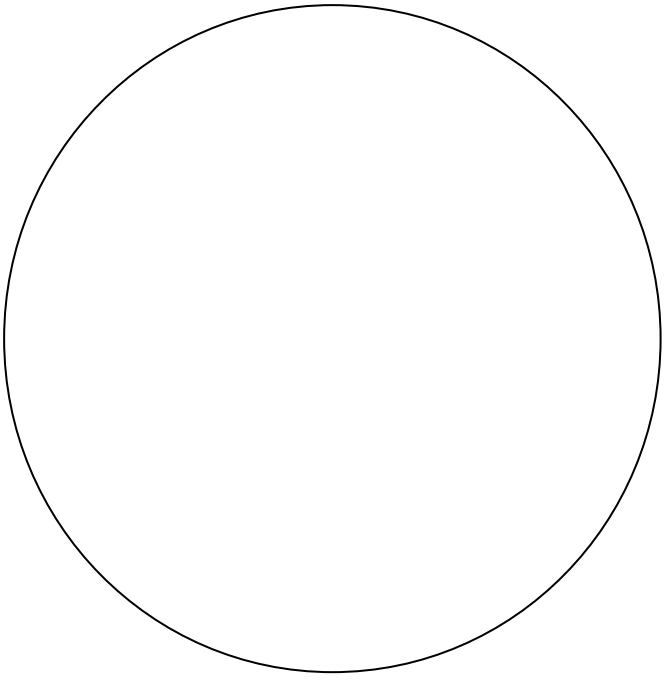




Quartz A) Draw a cross section of quartz (look at figure in book p. 110-111, P.G Read) B. Look at in the polariscope with conoscopic sphere

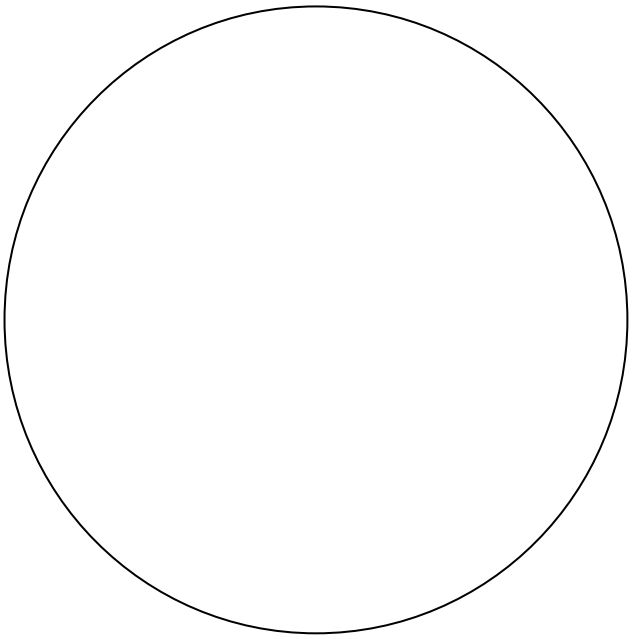
Give Approx. Magnification = without and with interference sphere



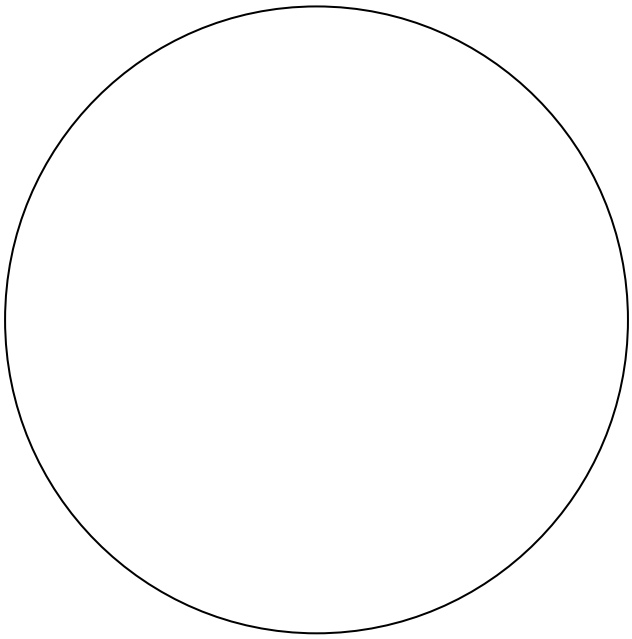


Draw a Rutilated quartz or tourmalinated Give magnification of whole crystal and microscope view (object x ocular magnifications = Total mag.)

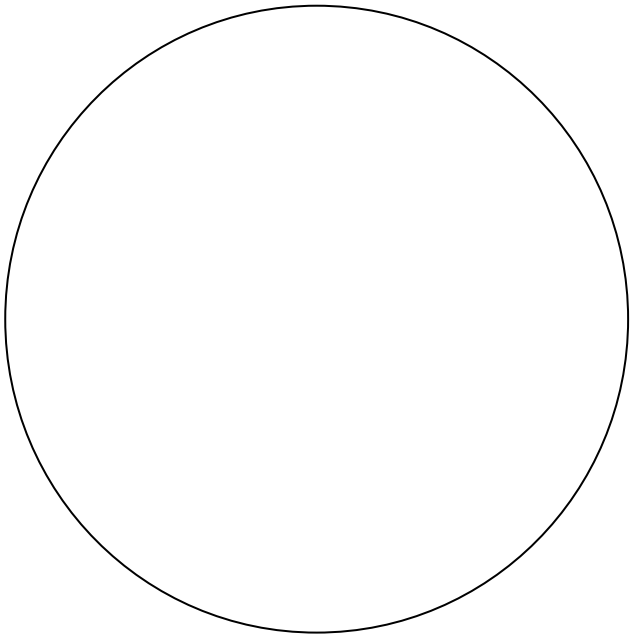
Whole Crystal



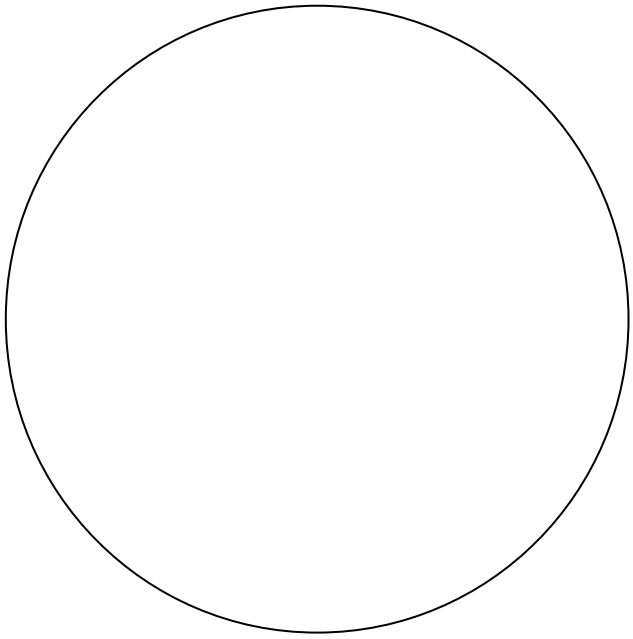
Microscope view rutile inclusion _____X



Hydrothermal quartz Whole Crystal
(see page 2 of handout and P. 178 of P. G. Read)



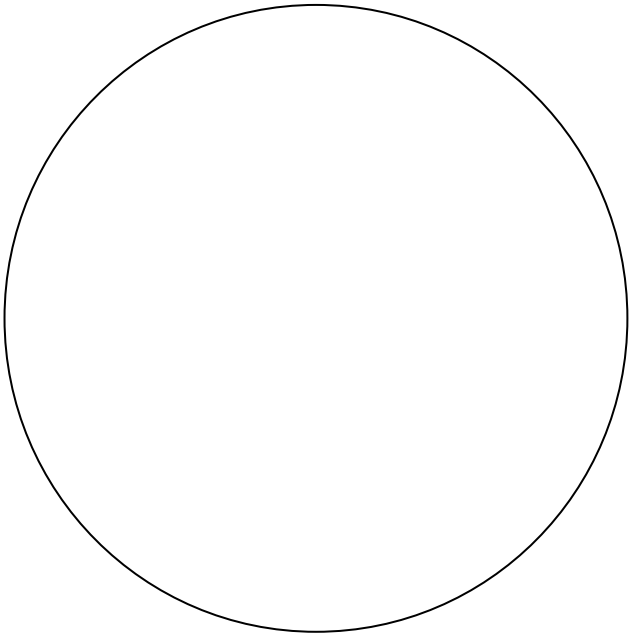
Microscope view of surface_____X



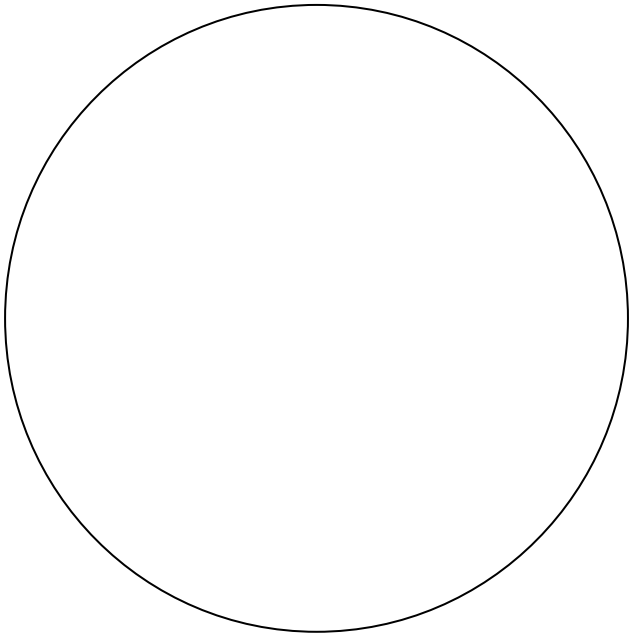
## Draw a tourmaline crystal

Give magnification of whole crystal and a close up of striations

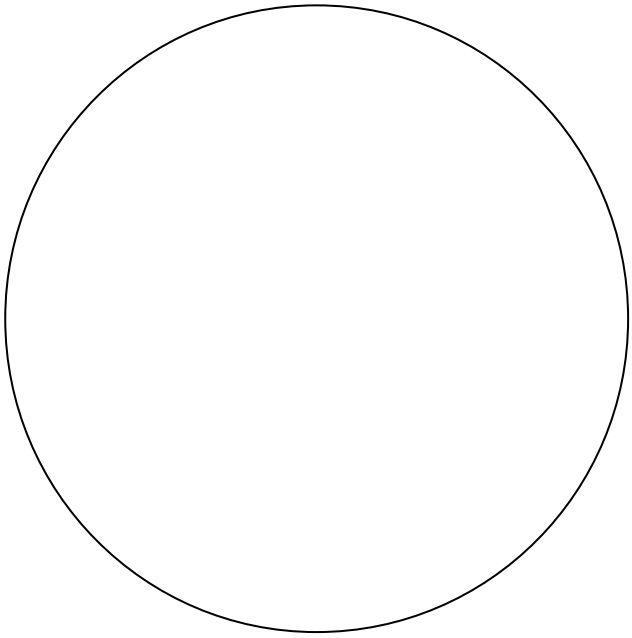
Tourmaline Crystal _____X



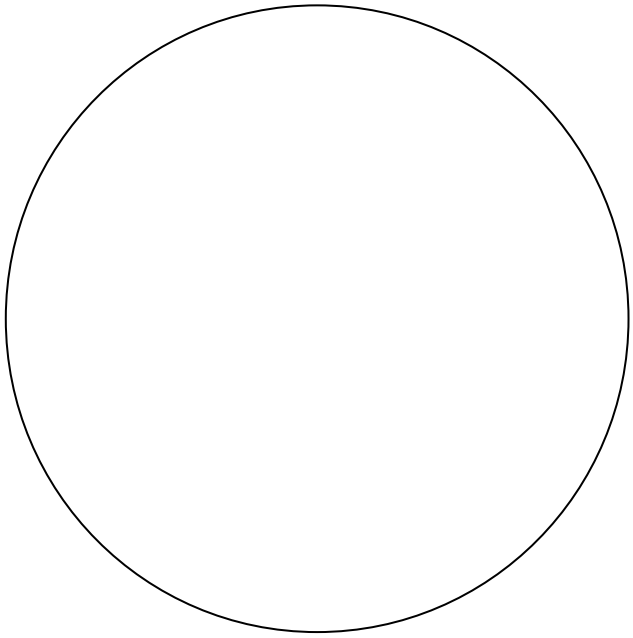
Close up of striations _____X



Tourmaline showing absorption parallel long direction _____x

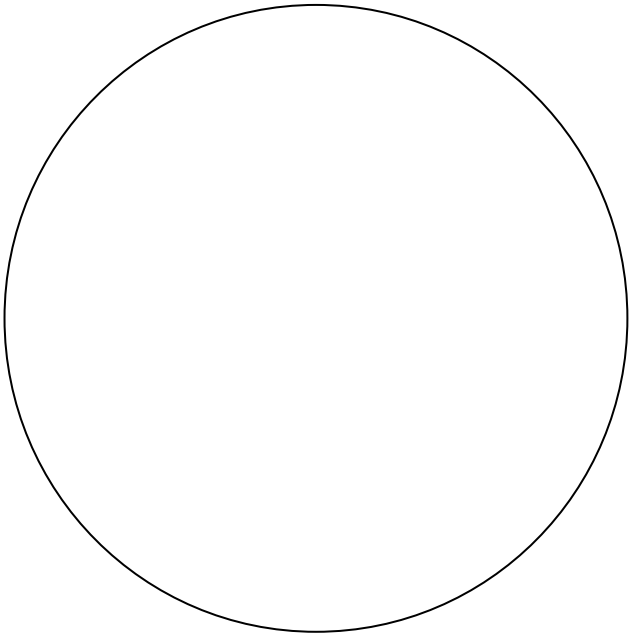


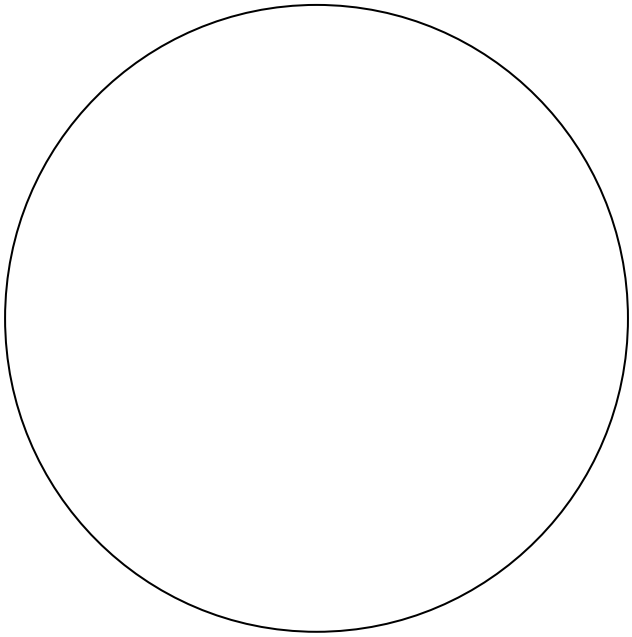
Same crystal 90$^{o}$ view _____X



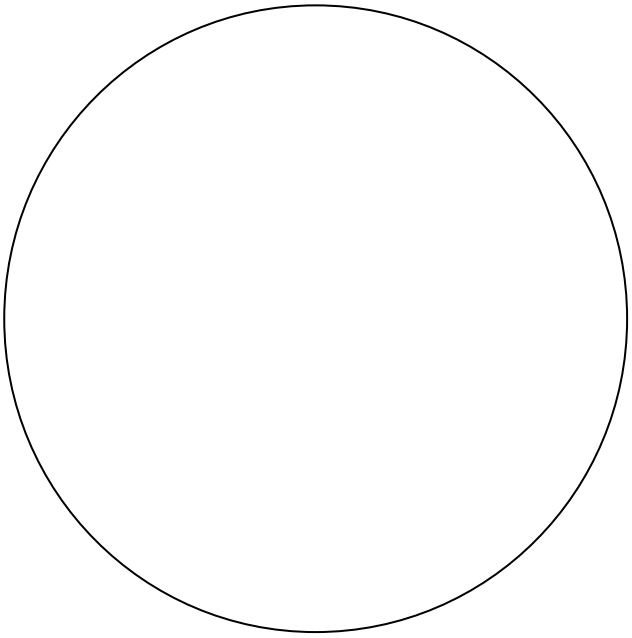
## Tourmaline with Conoscope (in book p. 110-111, P.G Read) Give drawing of whole crystal and view of the conoscope image

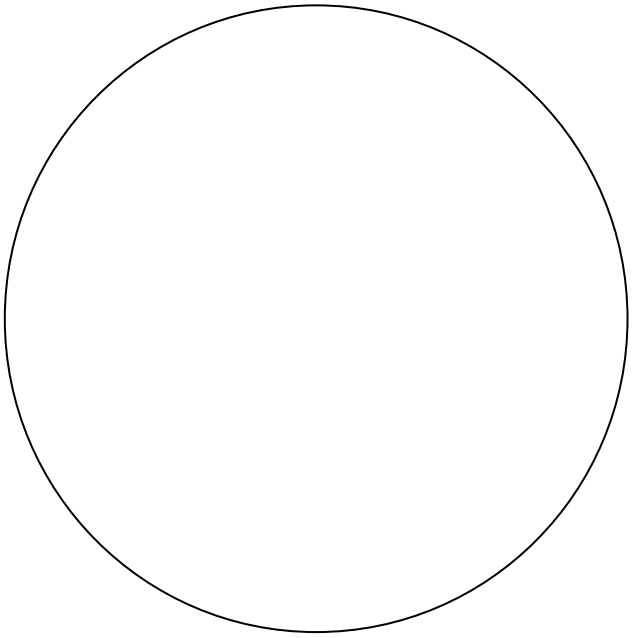
Whole stone ____X Conoscope of Tourmaline view _____X



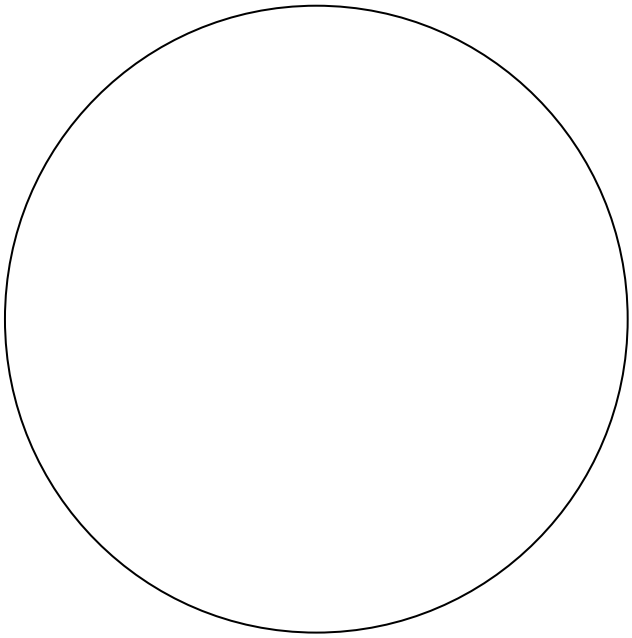


Whole cut stone Tourmaline Cat's eye Microscope view of tourmaline cat's eye _____X

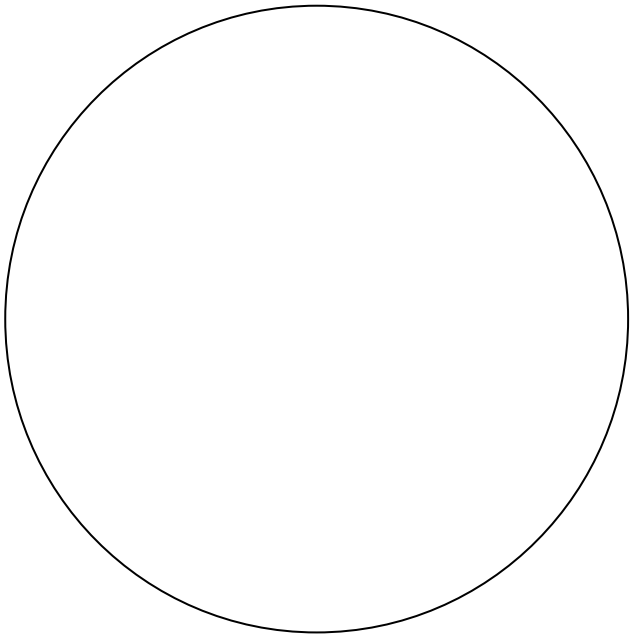




Cut tourmaline whole view

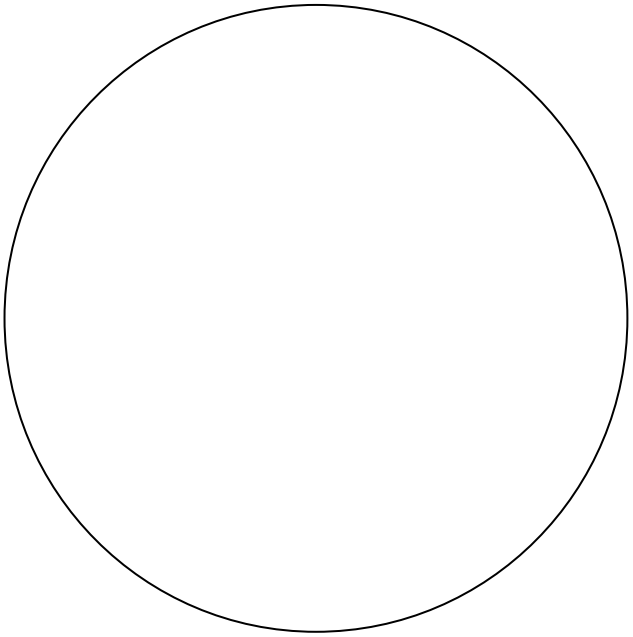


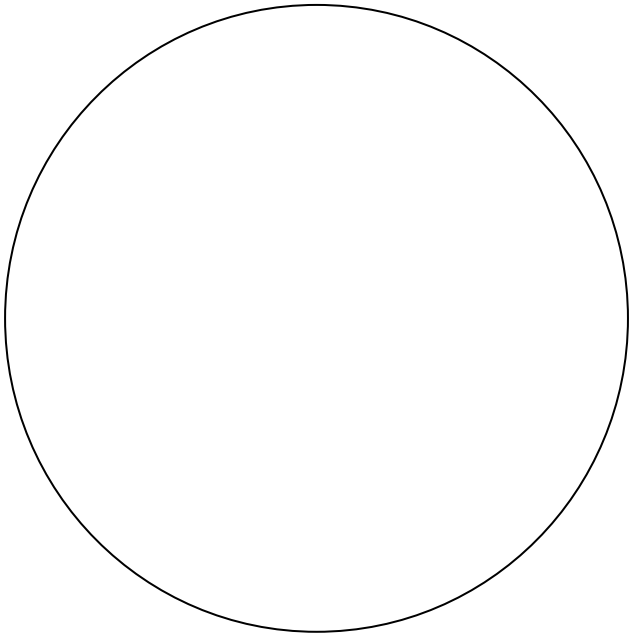
Microscope view Tourmaline inclusions_____X



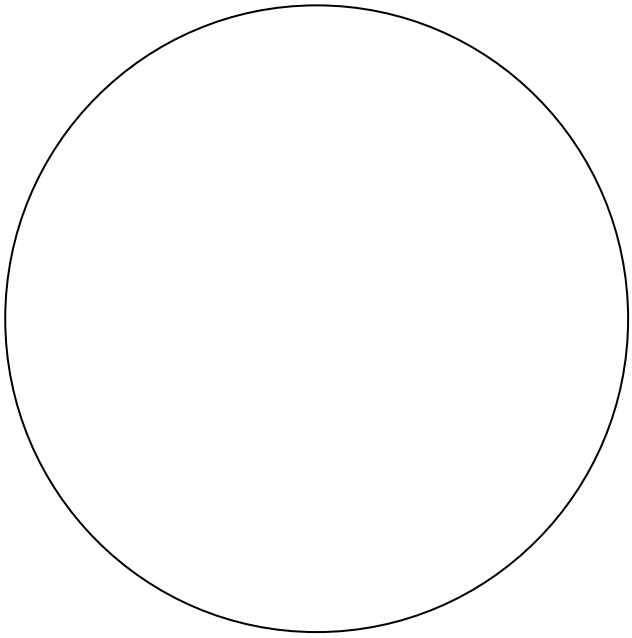
Draw a Cabochon Chrysoberyl Cat's eye, Cymophane. Give magnification of whole crystal and microscope view (object x ocular magnifications = Total mag.)

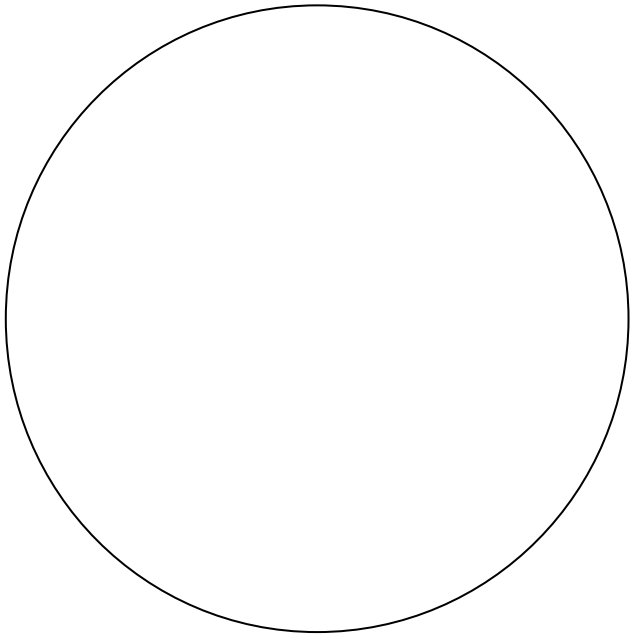
Whole stone Microscope view of inclusions (parallel tubes) (P. 75 Read) _____X





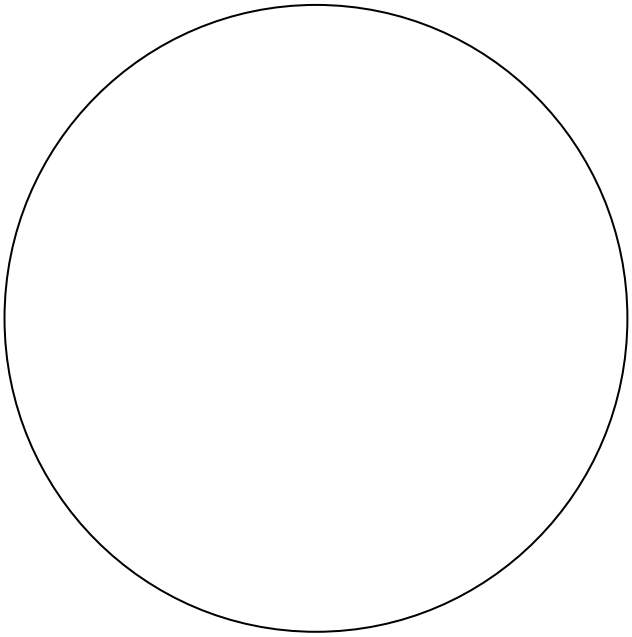
Regular Chrysoberyl (not cat's eye) Whole cut stone Microscopic inclusions if any _____X

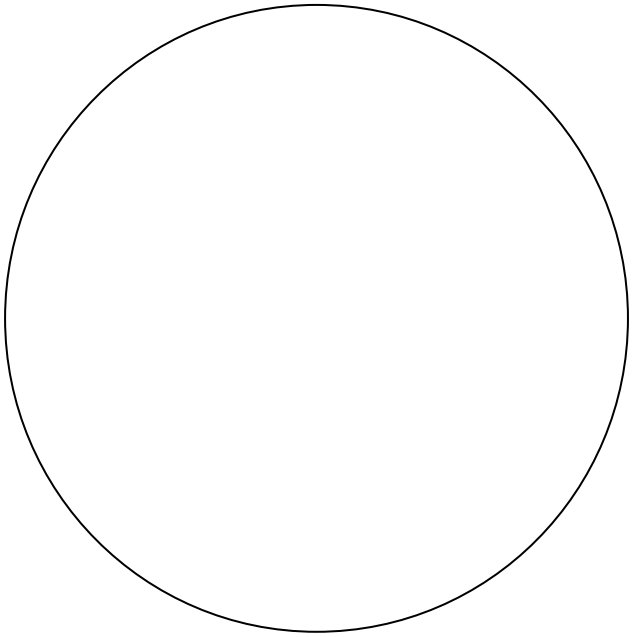


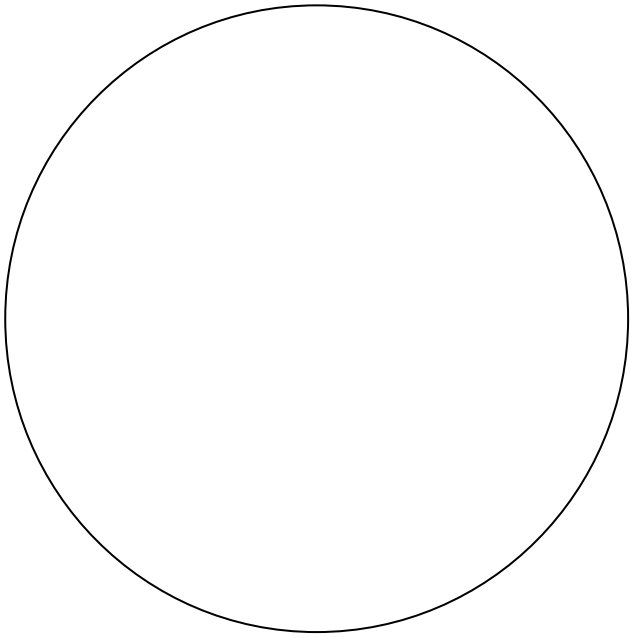


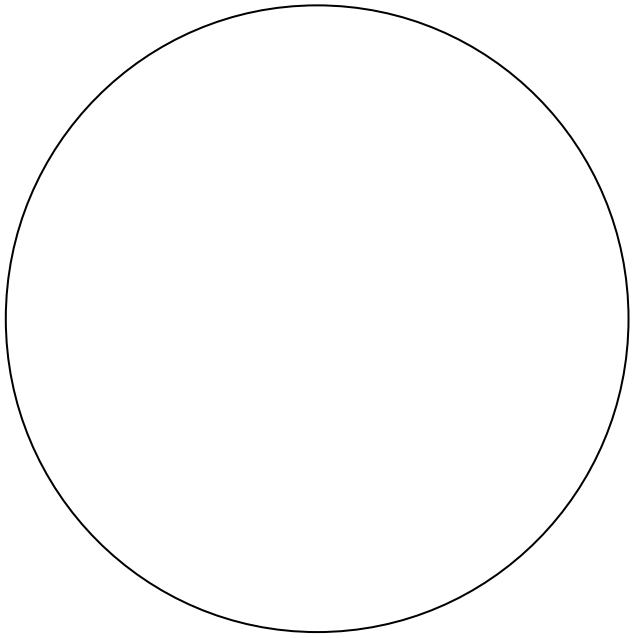
## Synthetic Alexandrite with inclusions (Chatham; flux) Give magnification of whole crystal and microscope view (object x ocular magnifications = Total mag.)

Syn. Alex crystal Microscope inclusions flux and or platinum _____X



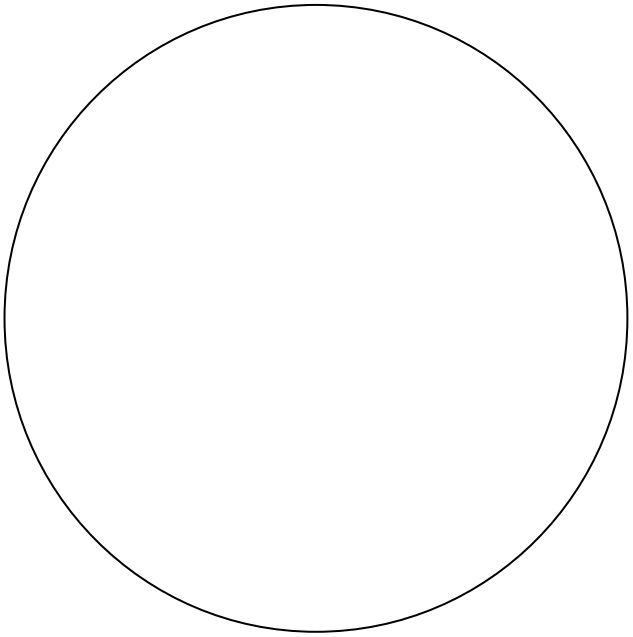




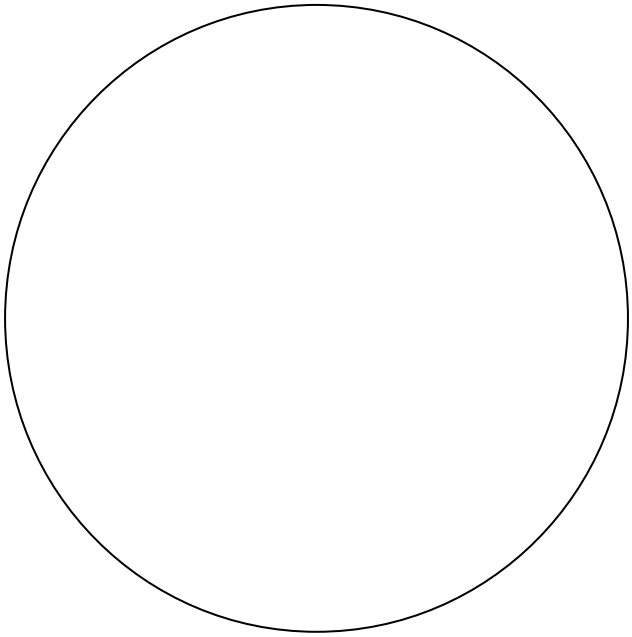


Zircon crystal Give magnification of whole crystal and microscope view (object x ocular magnifications = Total mag.)

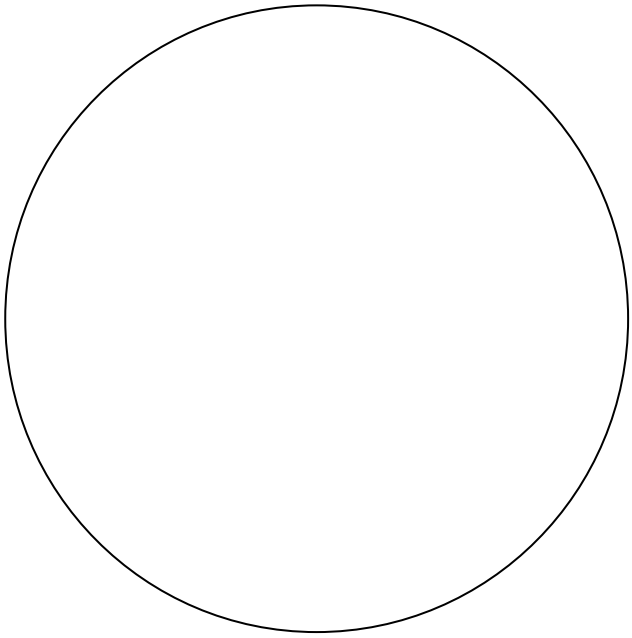
Whole zircon crystal



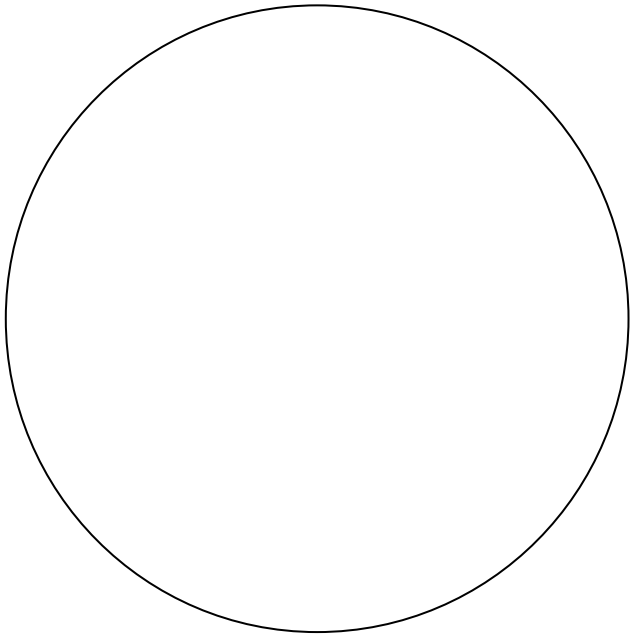
Microscope inclusions in Green metamict zircon_____X



Whole cut stone



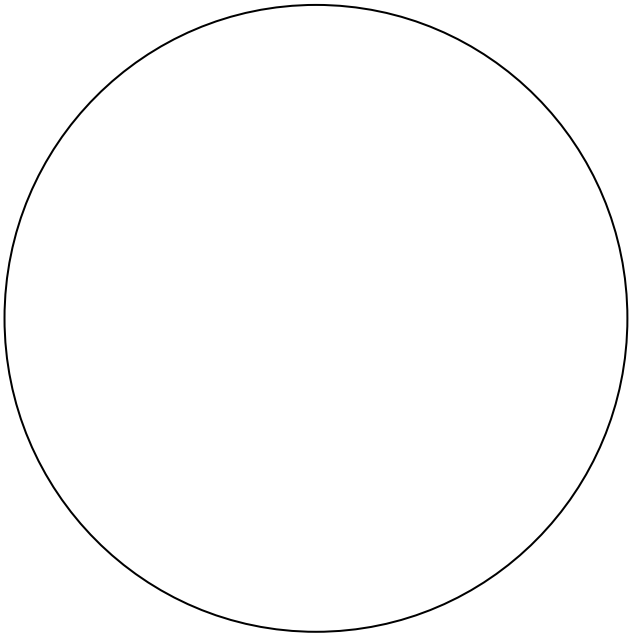
Colorless zircon with doubling of facets _____X



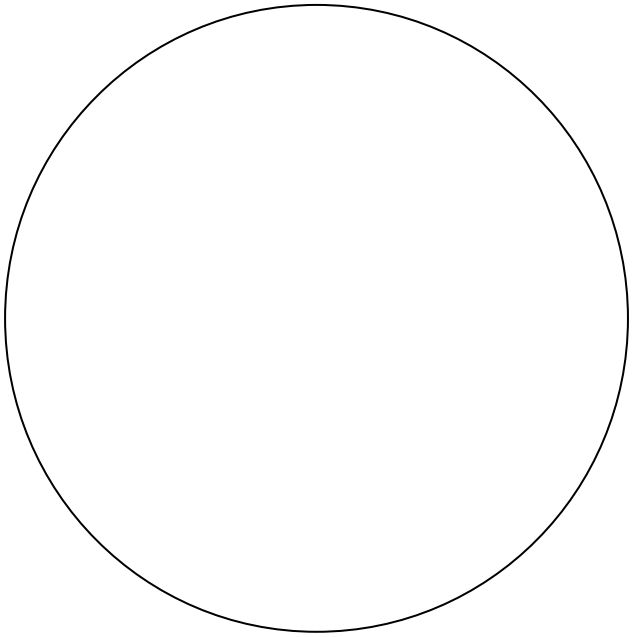
## Gilson Synthetic Opal Lizard Skin

Give magnification of whole crystal and microscope view (object x ocular magnifications = Total mag.)

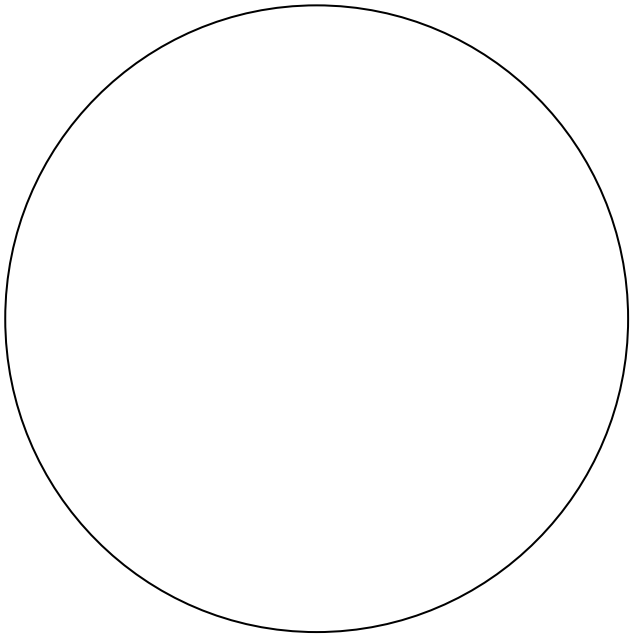
Whole cabochon



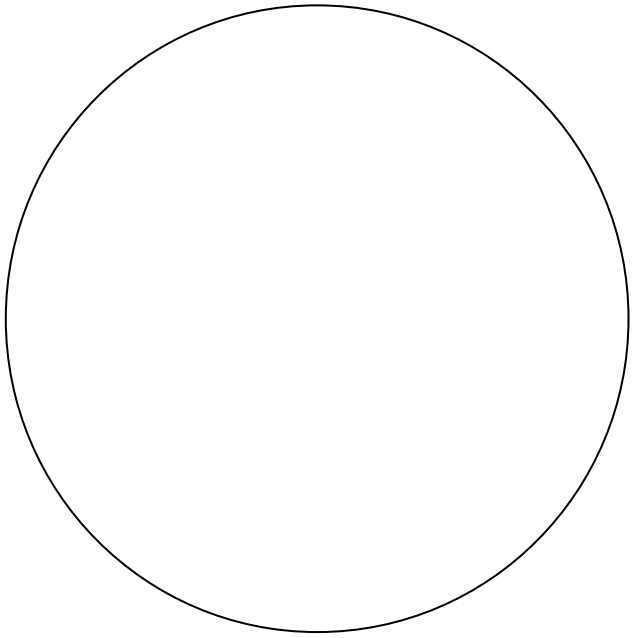
Microscope view of lizard skin _____X



Opal plastic impregnated parallel slice

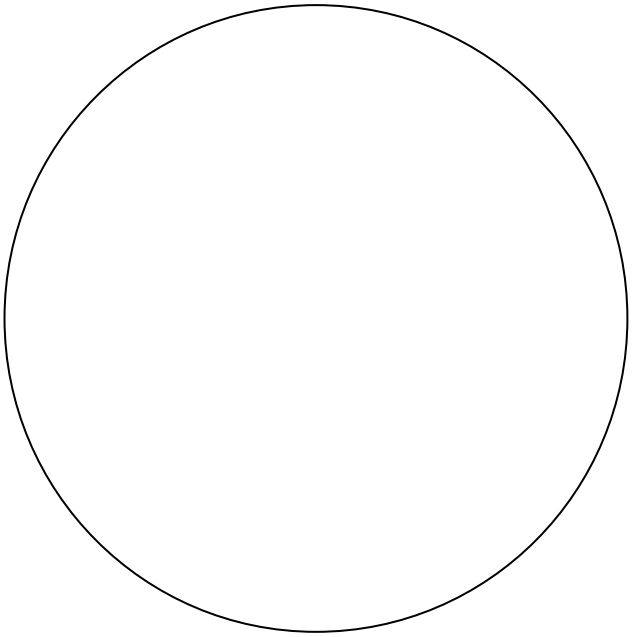


Plastic opal top view 90$^{o}$ to columns _____X

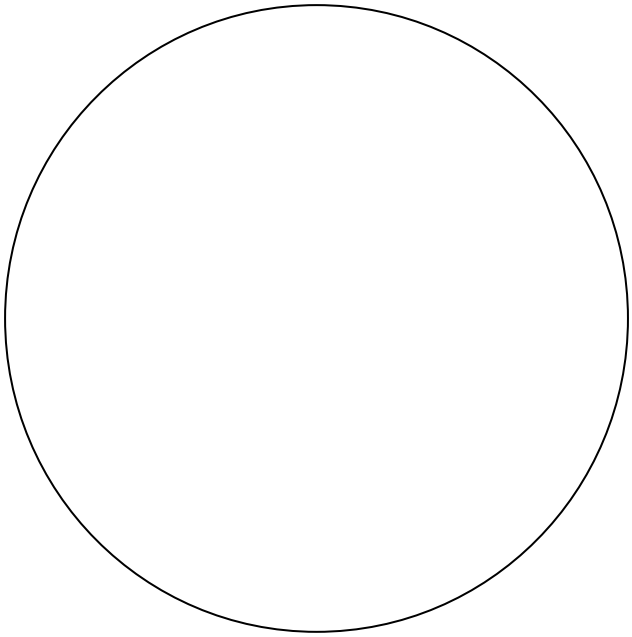


# Hydrophane Opal demonstration

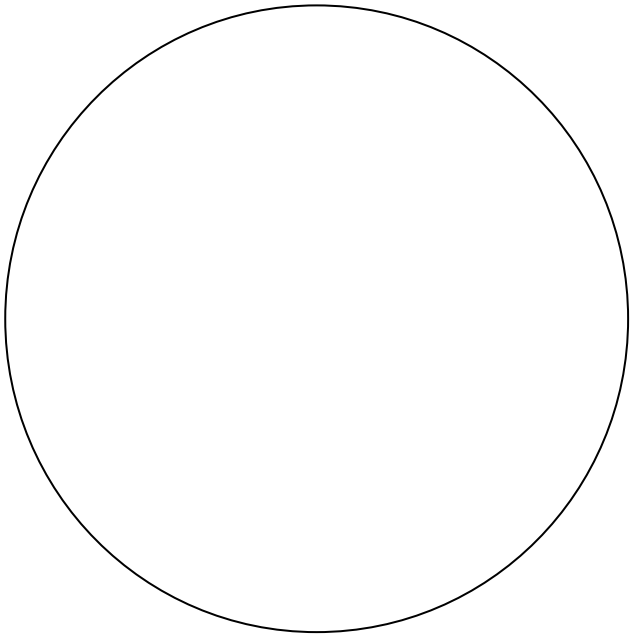
Before dipping in water

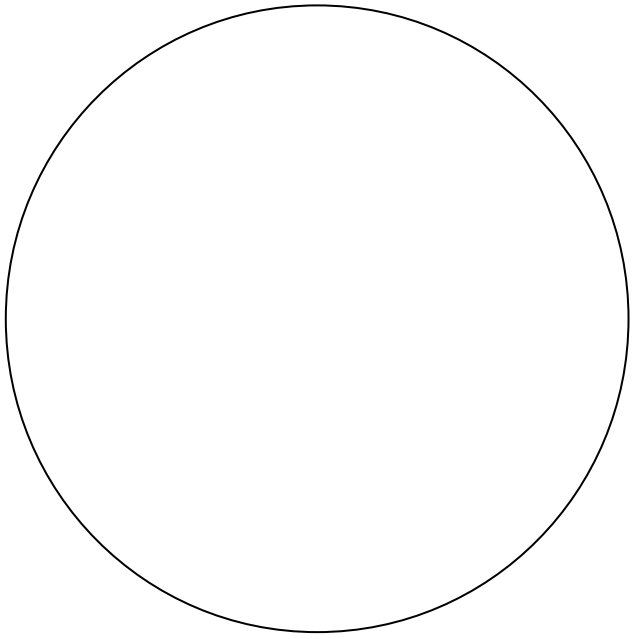


while dipping in water _____X



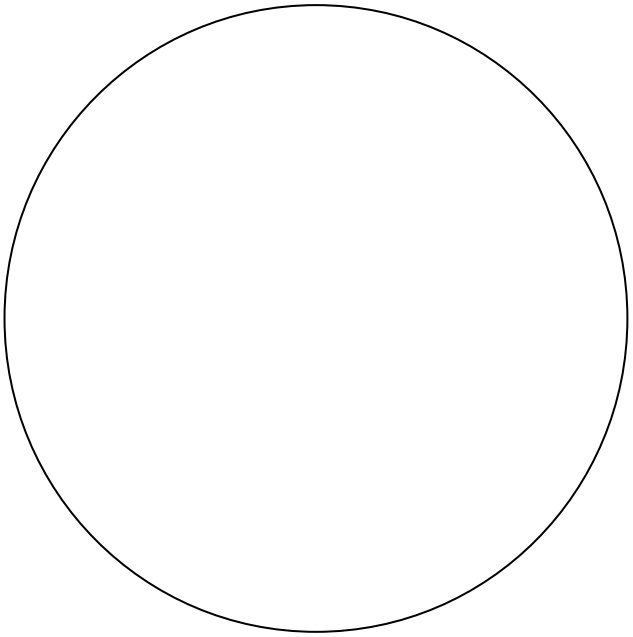
After dipping in water!

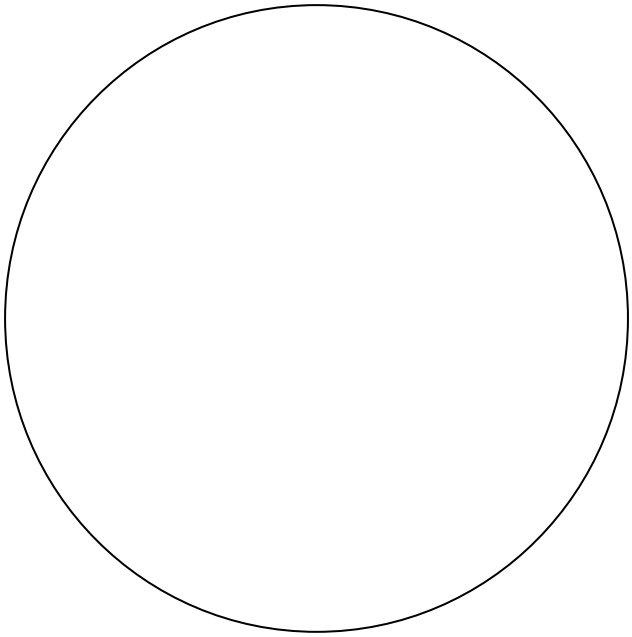




# Opal demonstration Pseudomorphs after ooids.

Draw oolite (a rock made of ooids) from Pennsylvania, USA





Draw microscopic ooids in **sugared Andamooka (Australia) Opal  Cabochon**