

Name: _____
Partner(s): _____

AST 112: Lab #3

The Celestial Sphere

Objectives

- *To use celestial coordinates to locate objects in the sky*
- *To locate objects in the sky with the Celestial Sphere and other sky charts*
- *To determine when objects in the sky will be visible in the night sky*
- *To determine the position of the Sun against the background of the stars*
- *To sketch a variety of constellations as they appear on the night sky using the Celestial Sphere*
- *To note the constellations of the zodiac and approximately the dates the Sun will cross in front of them*

Materials

- Celestial Sphere
- Star wheel
- Star chart
- Flip chart

References

- *Lab Manual for AST 102*, Hopkins
- *The Constellations: An Enthusiast's Guide to the Night Sky*, Motz & Nathanson
- *Norton's Star Atlas and Reference Handbook*, 20th ed., ed. Ridpath
- *The Box of Stars*, Tenant

Introduction

In ancient times, people believed the Earth was immobile and surrounded by a sphere to which the stars were attached. This *Celestial Sphere* would revolve about the Earth once each day, carrying the stars along with it. While today we know the Earth is the object that moves, it is still convenient to describe the sky in this manner for the purpose of determining the positions of objects in the sky (a science called *astrometry*).

We will use a model Celestial Sphere (and other sky charts) to describe the positions and appearances of various stars and constellations. We will also evaluate when certain objects will be visible in our night sky from our location.

Activity #1: Describing the Celestial Sphere

Before we use the Celestial Sphere, we need to carefully look it over & understand how it works. Students will work in small groups for this lab's activities; make sure each student has an opportunity to use the sphere.

- (a) Each group needs a representative to retrieve a Celestial Sphere from the instructor.
- (b) Which famous object is at the center of the sphere? Is it concentric to the outer sphere, or off center?
- (c) The object at the center has various lines (arcs) drawn on it. What do these represent? How are the arcs labeled? What unit(s) of measurement do they use?
- (d) The outer sphere also has labeled arcs. Answer the following:
 - i. Many arcs start from the "top", go vertically down the outer sphere, and end at the "bottom". Astronomers call these arcs of *Right Ascension*. What do they resemble?
 - ii. What directions do the "top" and "bottom" really represent?
 - iii. How many Right Ascension (*RA* for short) arcs are there? Is this a familiar number? Why or why not?

- iv. How many degrees are between successive arcs of RA (i.e. how wide is each “slice” in terms of RA)? Briefly explain your reasoning below.

- v. Other arcs go horizontally around the outer sphere, making complete circles. Astronomers call these arcs of *declination*. What do they resemble?

- vi. What is the measurement of declination (*dec* for short) at the bottom of the sphere? At the top? Around the middle?

- vii. Where is the largest declination circle? What does it resemble?

- viii. Astronomers will often describe features on the Celestial Sphere with the word “celestial”. For example, the extension of the North Pole to the sky is called the *North Celestial Pole* (or *NCP*). Sum up our findings by filling the Earth-based analogs to the Celestial Sphere in Table 3-1.

Table 3-1. Terms used for the Celestial Sphere.

Celestial Sphere term	Earth-based term
Right Ascension	
Declination	
Celestial Equator	
North Celestial Pole	
South Celestial Pole	

- (e) What is the represented by the small yellow ball (attached to a wire) that can be moved inside the Celestial Sphere?
- (f) The outer sphere has a circle of notches that follow the position of the yellow ball (this traces out what astronomers call the *ecliptic*). What do these notches represent?
- (g) The wire holding the yellow ball is attached to the outer sphere, but at an angle to the NCP. What is this angle?
- (h) The Moon and other solar system objects such as the planets are not included in this model. Why not?
- (i) What do the miscellaneous dots on the outer sphere represent? Why are some larger than others?
- (j) A thin, irregular fuzzy band makes a complete circle around the outer sphere. What does it represent? Is it aligned with the NCP and/or the ecliptic?

Activity #2: Locating Bright Stars on the Celestial Sphere

Table 3-2 lists coordinates for the ten brightest stars in the night sky for the year 2000.

- (a) Between the star charts, star wheels, and Celestial Sphere, identify each star by name and constellation. Record the results in Table 3-2.
- (b) Using the Celestial Sphere and/or the star wheel, determine whether each star will be visible in tonight's sky around 9 p.m. local time. Note the location (on Earth) and date in the space provided near Table 3-2. Write either "yes" or "no" in the space provided in Table 3-2.
- (c) Again using the Celestial Sphere, determine whether each star will be visible at all for our latitude or not. Write either "yes" or "no" in the space provided in Table 3-2.

Table 3-2. Locations of the Ten Brightest Stars.

Name of Star	Name of Constellation	Right Ascension (h m)	Declination (° ')	Visible at 9 pm?	Visible At All?
		06 45.2	-16 43		
		06 24.0	-52 42		
		14 15.7	+19 11		
		14 39.7	-60 50		
		18 36.9	+38 47		
		05 16.7	+46 00		
		05 14.5	-08 12		
		07 39.3	+05 14		
		05 55.2	+07 24		
		19 50.8	+08 52		

Activity #3: Locating and Drawing Prominent Constellations

Now we will use the Celestial Sphere to locate and describe constellations visible during various seasons or at certain latitudes. Each group will be assigned a set of constellations to locate and sketch. After finishing, each group will share their results with the rest of the class. The instructor may request each group share an example from their assigned set, using a flip chart. Answer the following questions first, then begin to sketch your assigned set.

- (a) While sketching your assigned set of constellations, note which constellations (if any) cross the ecliptic. These constellations belong to the *zodiac*.
- (b) How many constellations appear to cross the ecliptic? Is this the number you expected?
- (c) Are all of the zodiac constellations the same size? If not, which appears to be the largest? Which appears to be the smallest?
- (d) The term *zodiac* refers to a “zoo” of animal shapes. Are all of the zodiac constellations animals? If not, which constellations are not animals, and what are they instead?
- (e) Where possible, locate & label each object specified in the descriptions of the constellations.
- (f) Why is the Celestial Sphere transparent? How does that affect the sketching of each constellation?

- (g) The term *constellation* can be understood by considering the prefix “con” and the root “stella”. Why is this an apt term?
- (h) Astronomers have designated 88 “official” constellations. Do these cover the entire sky, or are there gaps?
- (i) The “picture” one can sketch of a constellation doesn’t have to look like the shape implied by the name of the constellation. Give an example below of one constellation that looks very much like its name, an example where the constellation partly looks like its name, and an example where the constellation doesn’t look anything like its name. Identify each constellation by name and (expected) shape.
- (j) An *asterism* is an unofficial grouping of stars, usually one that suggests an obvious or famous shape. Identify one famous asterism below, where to find it, and provide a sketch below.
- (k) Consider the word *consider*. What is its common meaning today? Given the prefix *con* and the root *sider*, what did it imply in the past?
- (l) For your assigned category, find the constellations listed, sketch a picture depicting the constellation in the space provided, and label any prominent objects. Indicate the directions North and East in your sketch. Descriptions of constellations are on the following pages along with space for sketches.

The Northern Circumpolar Sky

Ursa Major: Among the largest of the constellations, the big bear is one of a select few that are visible during the entire year for most northern hemisphere observers. Within the big bear is one of the most famous asterisms, the Big Dipper. The dipper consists of seven bright stars in an easily recognizable shape and forms the tail & back of the big bear. The stars at the end of the dipper point towards the North Star. The second “star” of the handle of the dipper is actually two stars, separable by those with keen eyesight. Although *Mizar* and *Alcor* appear close to each other, in fact they are very far apart. The accidental alignment of two stars is referred to as an *optical double*. Sketch Ursa Major and label Mizar and Alcor.

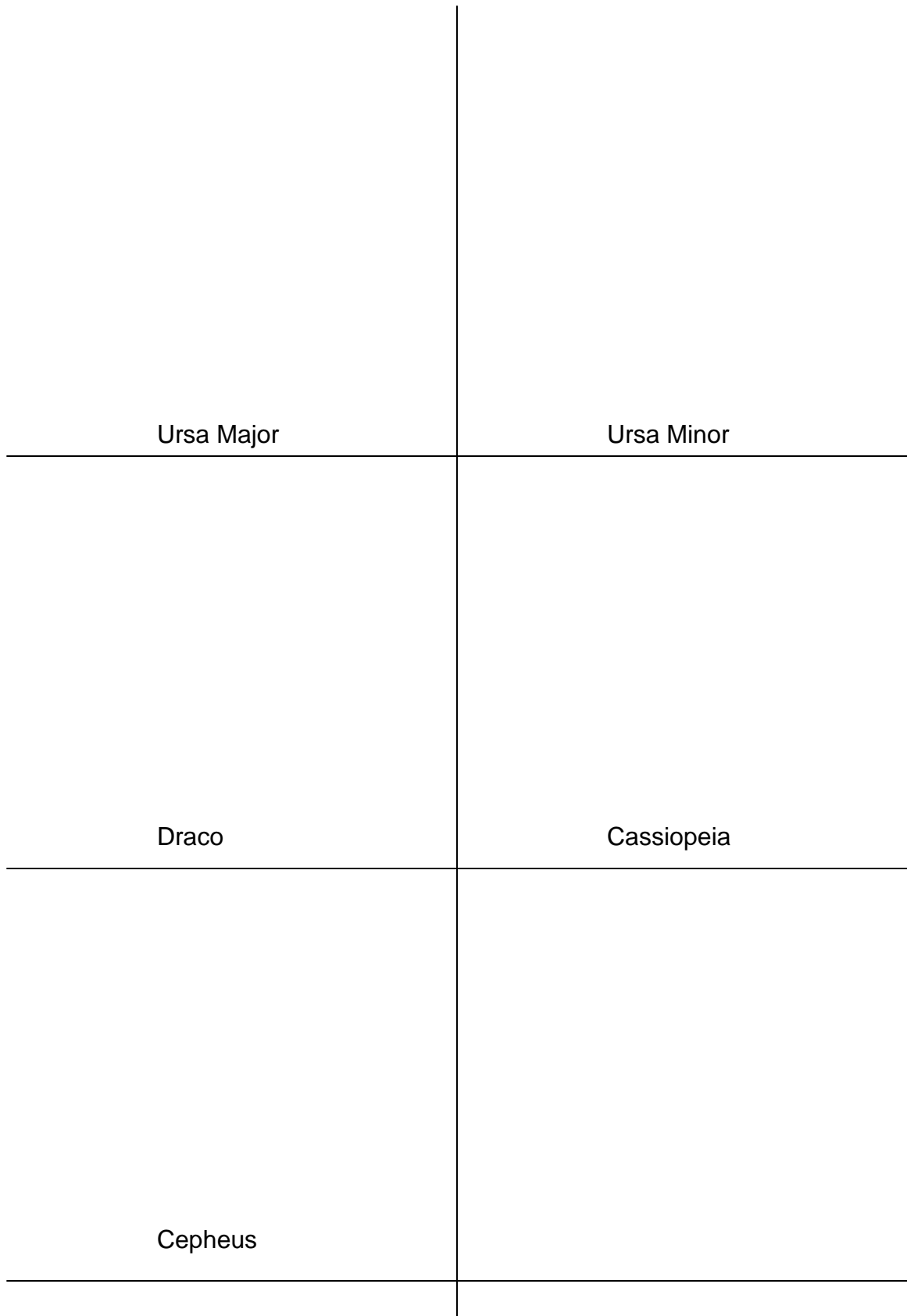
Ursa Minor: The little bear is also in the shape of a dipper of sorts, and thus is often called the Little Dipper instead (indeed, the Little Dipper and Ursa Minor are the same stars). The little bear represents the son of the mother big bear, both of whom were originally human beings. Threatened by hunters, they were placed in the sky by the Greek god Zeus. On most nights, only the two end stars and the end of the handle are visible. At the end of the handle is *Polaris*, which is less than one degree from the North Celestial Pole (NCP). All stars in the sky appear to rotate about *Polaris* during the night. Sketch Ursa Minor and label *Polaris*.

Draco: The dragon coils around the pole star, guarding the gates of immortality and holding the pole of the sky in place. Most of the dragon’s stars are dim, but one in particular deserves attention. *Thuban*, the brightest star in the dragon, marked the NCP 5000 years ago. The precession of the Earth’s axis has since moved the NCP toward *Polaris*, which will be at its closest to due north in the year 2095. Sketch Draco and label *Thuban*.

Cassiopeia: The queen of ancient Ethiopia sits (sometimes upside-down) on her throne in the northern skies. The mother of Andromeda, she is recognizable by her “M” or “W” asterism. It was here that Tycho Brahe observed the supernova of 1572, which led to the demise of the Earth-centered model of the solar system. Sketch Cassiopeia.

Cepheus: The king of Ethiopia also sits on a throne, but face-on instead of in profile as Cassiopeia. He is not as easy to recognize because his stars are not as bright. His left foot points toward the NCP and he is sitting between Cassiopeia and Draco. Delta (“ δ ”) Cephei, a star that helps make up his crown, is one of the most useful stars in the sky, because allows astronomers to determine the distances to far away galaxies. Sketch Cepheus and label Delta Cephei.

Northern Circumpolar Constellations



The Winter Sky

Gemini: This constellation contains two of the brighter stars in the sky, *Castor* and *Pollux*, who were twin sons of different fathers in Greek mythology. Blue-colored Castor actually is a system of six stars, whereas Pollux is a single yellow giant. Sketch Gemini and label both Castor and Pollux.

Auriga: The tip of the northernmost horn of Taurus also belongs to Auriga. Zeus placed the crippled Erichthoneus in the sky for the invention of the chariot. The charioteer sits facing us, making an irregular shape of several bright stars including Capella, a four-star system. Sketch Auriga and label Capella.

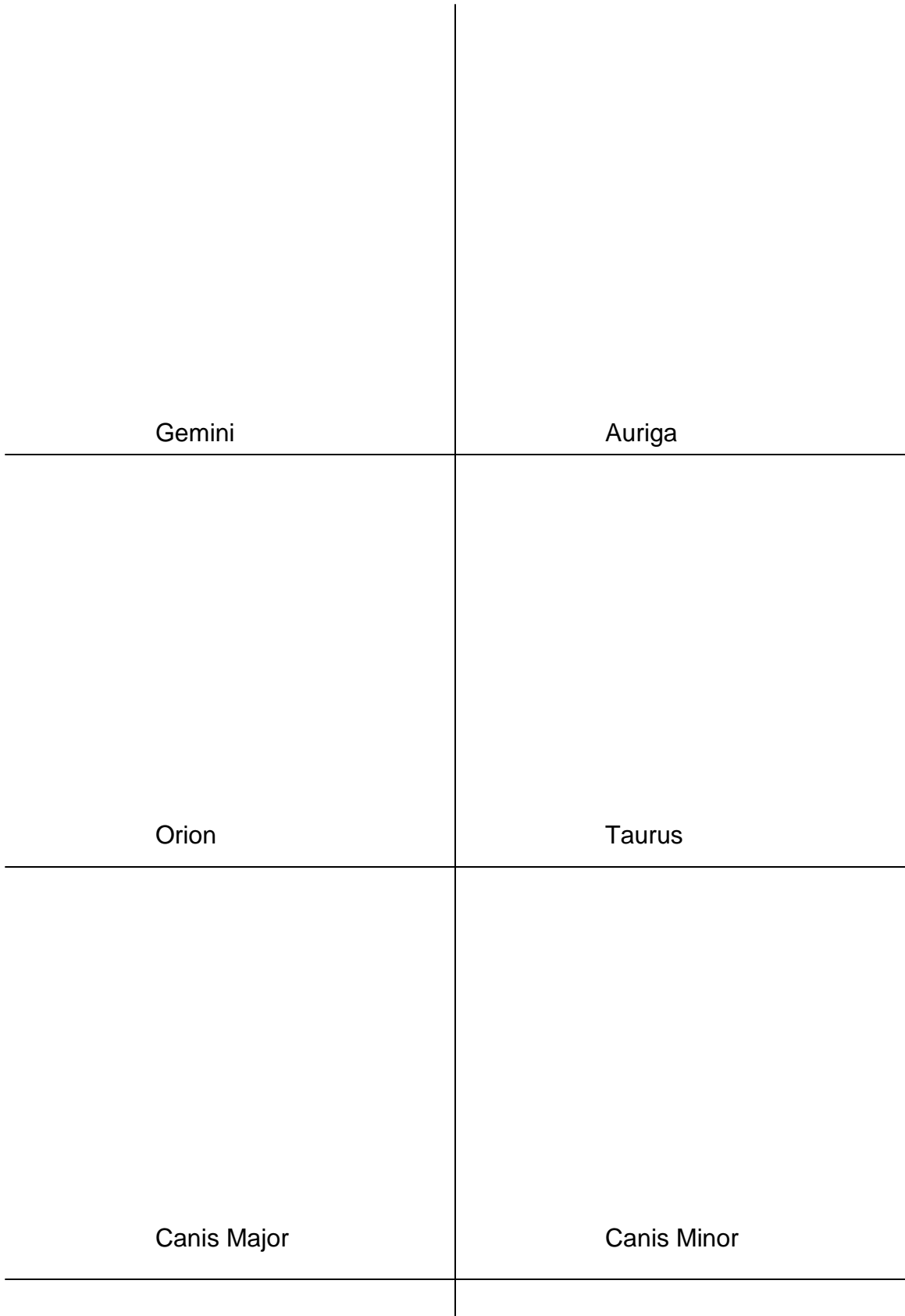
Orion: The most spectacular of the winter constellations, Orion is immediately recognizable by his belt. Three stars of near-equal brightness are lined up in a row, marking the position of the Celestial Equator. The bright red star to the northeast of the belt is *Betelgeuse*, marking his shoulder, and the bright blue star to the southwest of the belt is *Rigel*, marking his knee. South of the belt lies a cluster of brand-new stars just emerging from their stellar birthplace, the *Orion Nebula (M42)*. Sketch Orion and label Betelgeuse, Rigel, and M42.

Taurus: North and west of Orion is the ancient constellation of the bull. Only the head & horns of the bull are shown, and he is sometimes described as charging at Orion. The brightest star in the bull is Aldebaran, which marks the eye of the bull. To the west of the bull is the Pleiades star cluster. Although the naked eye can only make out six or seven stars, a pair of binoculars reveals hundreds of young, blue stars and wisps of gas and dust. Sketch Taurus & the Pleiades and label Aldebaran.

Canis Major: Orion's faithful hunting dog, Canis Major, accompanies the hunter. The big dog helps Orion fend off the charging bull and chases after the nearby constellation of the rabbit, Lepus. The big dog, lying to the southeast of Orion, contains the brightest star in the night sky, *Sirius*. The Sirius holds one of the closest known white dwarfs, affectionately known as the *Pup*. Sketch Canis

Canis Minor: About as small as a constellation can get, the little dog was added to the sky a few centuries ago almost as an afterthought. It is recognizable chiefly due to its bright star *Procyon* that, ironically, also has a white dwarf companion. Together with Betelgeuse and Sirius, Procyon makes up the asterism of the *Winter Triangle*. Between the big and little dogs lies another recently made constellation, *Monoceros* the unicorn, which is barely visible to the naked eye. Sketch Canis Minor and label Procyon.

Winter Constellations



The Spring Sky

Leo Major: Most commonly known simply as *Leo*, this constellation is easy to locate due to its fishhook-shaped head. The bright star *Regulus* sits at the base of the fishhook, or the lion's heart, and also marks the ecliptic. The bright star *Denebola* marks the lion's tail. The lion was the first of the legendary monsters slain by the hero Hercules. Sketch Leo and label Regulus and Denebola.

Cancer: The crab is a difficult constellation to spot due to its dim stars, but at the center of the crab lies a galactic cluster, *Praesepe (M44)*, also known as the beehive. The goddess Hera placed the crab in the sky after it was killed in her service by Hercules. Sketch Cancer and label M44.

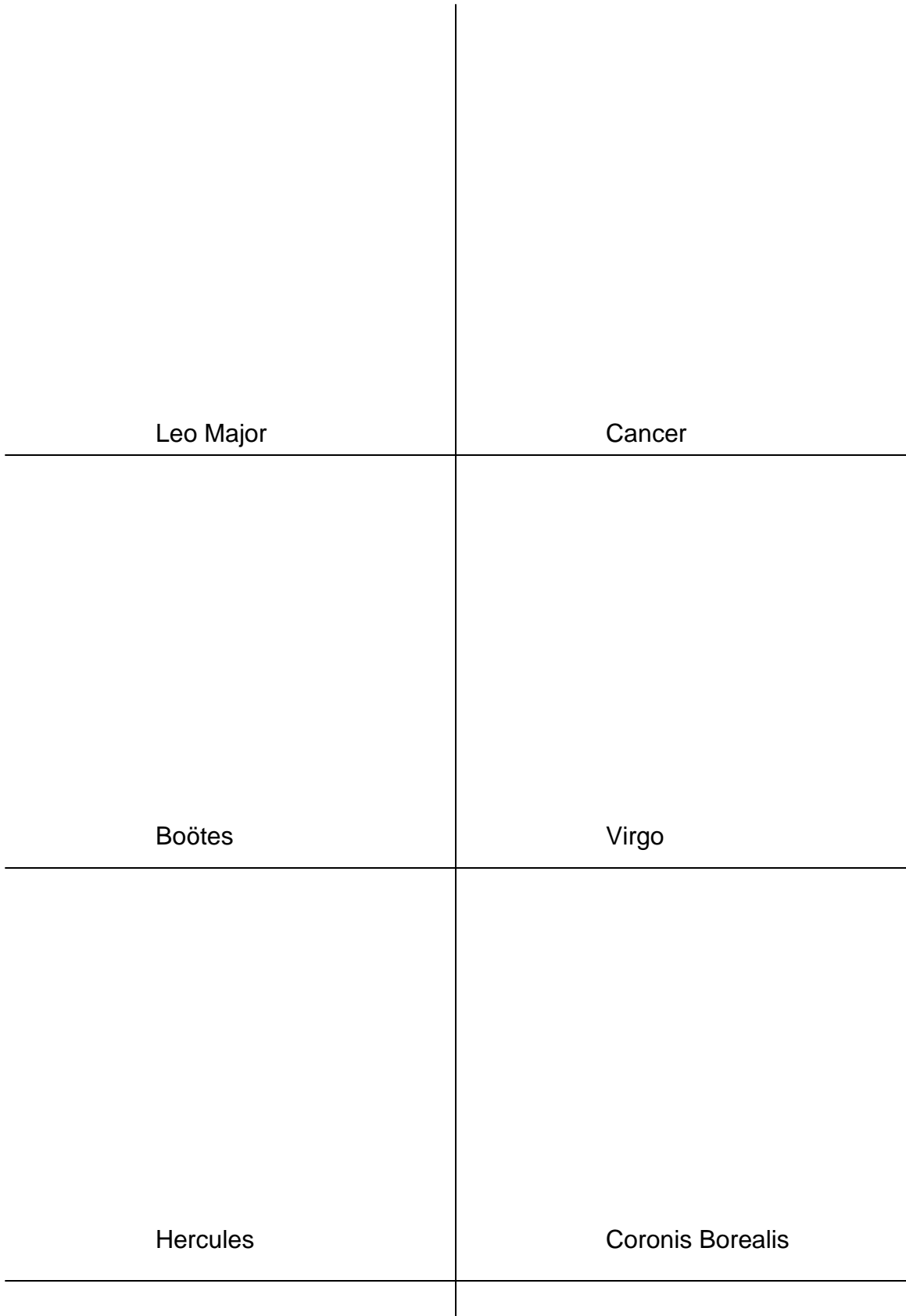
Boötes: The herdsman is to the north of the eastern end of Virgo and not far from the big bear. Boötes has the task of chasing the two bears around the sky, and is accompanied by his dogs, *Canes Venatici*. The brightest of his stars is *Arcturus*, a red giant at his left kneecap. Sketch Boötes and label Arcturus.

Virgo: One of the largest constellations, the maiden is shown lying down on a couch. She carries a grain of wheat in her left hand, marked by the bright star *Spica*. In one famous myth, she was Persephone, the daughter of the goddess Ceres, who was kidnapped by the god of the underworld, Hades. The rising of the maiden into the night sky announced that winter was coming to an end and that farmers should prepare to sow their fields. Sketch Virgo and label Spica.

Hercules: The greatest of Greek heroes is found to the east of Corona Borealis. If one looks at Hercules while facing south, one finds the hero upside-down. Once this is realized, the figure of the kneeling Hercules can be distinguished. The stars of Hercules tend toward average brightness, although the moderately bright star *Ras Algethi* can be seen to represent his head. Near his right hip is the globular cluster *M13*, a grouping of hundreds of thousands of old, red stars. Sketch Hercules and label both Ras Algethi and M13.

Corona Borealis: The crown of the north was a gift from the god Dionysus to the young girl Ariadne, who had been stranded on the island of Naxos by the Greek hero Theseus. After Ariadne's death, Dionysus placed the crown in the sky between Hercules and Boötes. Although the stars of the crown are not exceptionally bright, the two brightest stars, *Alpha (α)* and *Beta (β) Coronis*, are of interest because they are traveling through space at high speeds. The two stars in fact have exchanged positions within the last few thousand years. Sketch Corona Borealis and label both Alpha and Beta Coronis.

Spring Constellations



The Summer Sky

Cygnus: The constellation of the swan also contains one of the more easily recognizable asterisms, the *Northern Cross*. The bright blue supergiant *Deneb* marks the tail end of the swan (or the top of the cross) and the neck of the swan extends to the southwest until ending at another bright star, *Alberio*. Much of the Milky Way passes through Cygnus. Cygnus is also the home of the most famous of black holes, Cygnus X-1. Sketch Cygnus and label Deneb and Alberio.

Lyra: The harp once belonged to the best musician of the ancient world, Orpheus, and was placed in the heavens after his death by Zeus. Its brightest star, *Vega*, is the brightest of the northern stars during summer evenings, and used to mark the NCP about 12,000 years ago. The rest of the constellation is composed of a tiny parallelogram of stars (the “strings” of the harp) to the southeast of Vega. Sketch Lyra and label Vega.

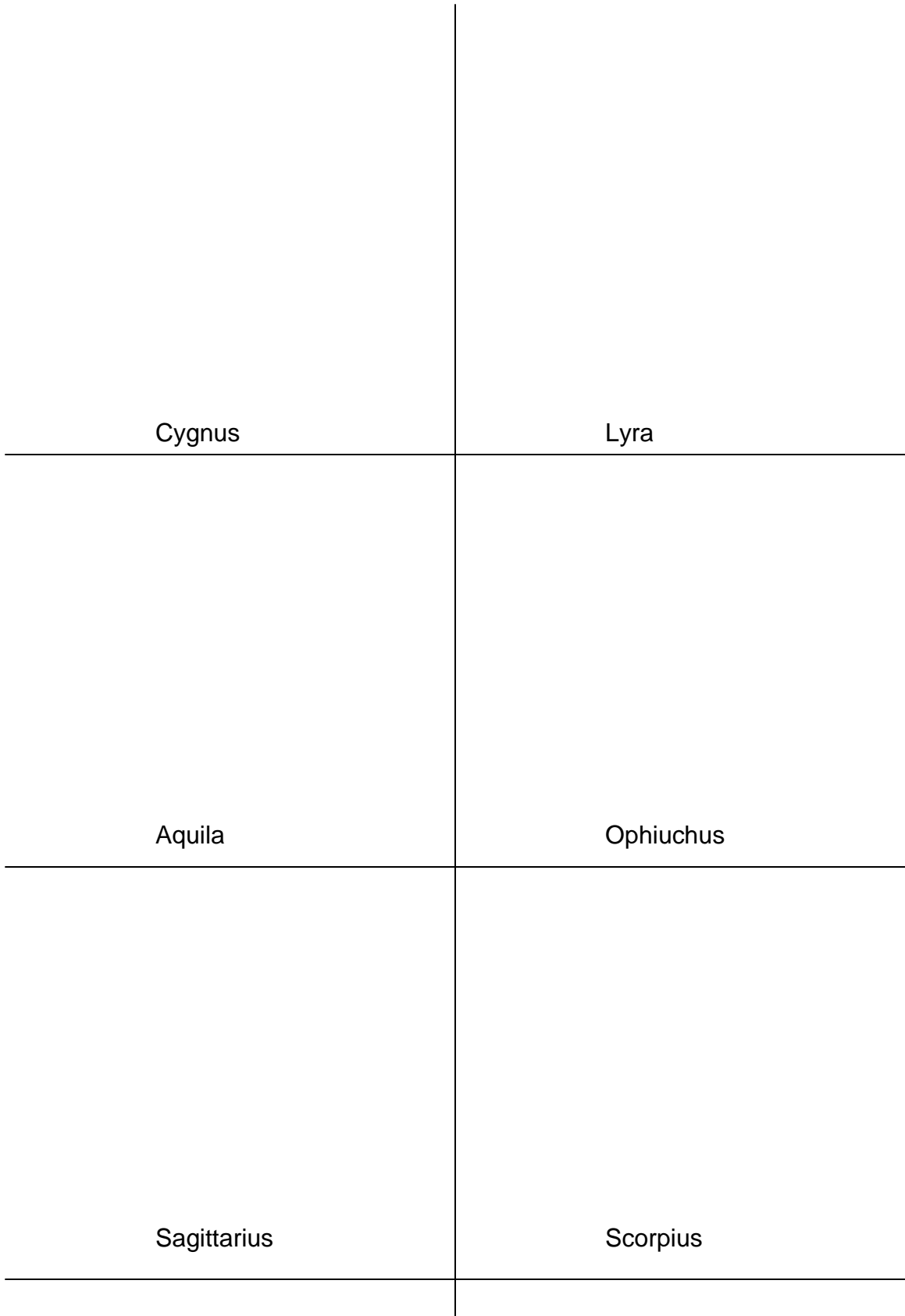
Aquila: When the goddess Hebe married Hercules upon his arrival at Mount Olympus, the gods needed a new cupbearer. Zeus sent his avatar, the eagle, to fetch prince Ganymede of Troy (a generation before the famous war). In reward, Zeus placed his bird in the sky. The heart of the eagle is denoted by *Altair*, a star whose shape is distorted by its fabulously quick rotation (once every 6 hours). With Deneb and Vega, Altair makes up the asterism of the *Summer Triangle*. Sketch Aquila and label Altair.

Ophiuchus: Also called Serpentarius, Ophiuchus contains no bright stars. It does however have a distinct shape (his central section looks like a house) and covers a large portion of the sky. The doctor is located south of Hercules and represents Aesculapius, a son of the god Apollo who supposedly could raise the dead in defiance of the gods. Ophiuchus holds a serpent (a symbol of immortality) with both hands, the head of the serpent bent to the west. Ophiuchus is also the home constellation of *Barnard’s star*. Sketch Ophiuchus.

Sagittarius: One of two centaurs – half-horse, half-man creatures – in the night skies, he is holding a bow & arrow cocked toward the west. The archer is more easily found by looking for the *teapot* asterism and is famous among astronomers for being the direction of the center of the Milky Way galaxy. Sketch Sagittarius.

Scorpius: The scorpion is among the easiest of constellations to find, although it usually only spends a few hours above the southern horizon. It looks like a fishhook with the bright red giant star *Antares* at the scorpion’s heart. Under the orders of the Earth goddess, the scorpion fought & killed the hunter Orion after he bragged about his abilities to kill monsters. The two are now at opposite ends of the sky to keep them out of further trouble. Sketch Scorpius and label Antares.

Summer Constellations



Autumn Constellations

Andromeda: Andromeda was the maiden chained to a cliff in order to be sacrificed to the sea monster Cetus. None of the stars in Andromeda is particularly bright, but one of the objects of special interest is *M31*. *M31* looks like a dim star, but in reality is a giant spiral galaxy like the Milky Way. At a distance of nearly 3 million light years, it is among the furthest objects one can see with the naked eye. Sketch Andromeda and label *M31*.

Pegasus: The most recognizable feature of Pegasus is the asterism of the *Great Square*, consisting of four nearly equally bright stars in the (approximate) shape of a square nearly 15 degrees on a side. The northeastern star of the square officially belongs to Andromeda. The winged horse is upside-down, only shows the front half of his body (sans wings) and faces the west. Strangely, the beautiful winged horse is the offspring of the snake-headed Medusa, whose glance turns people to stone. Sketch Pegasus.

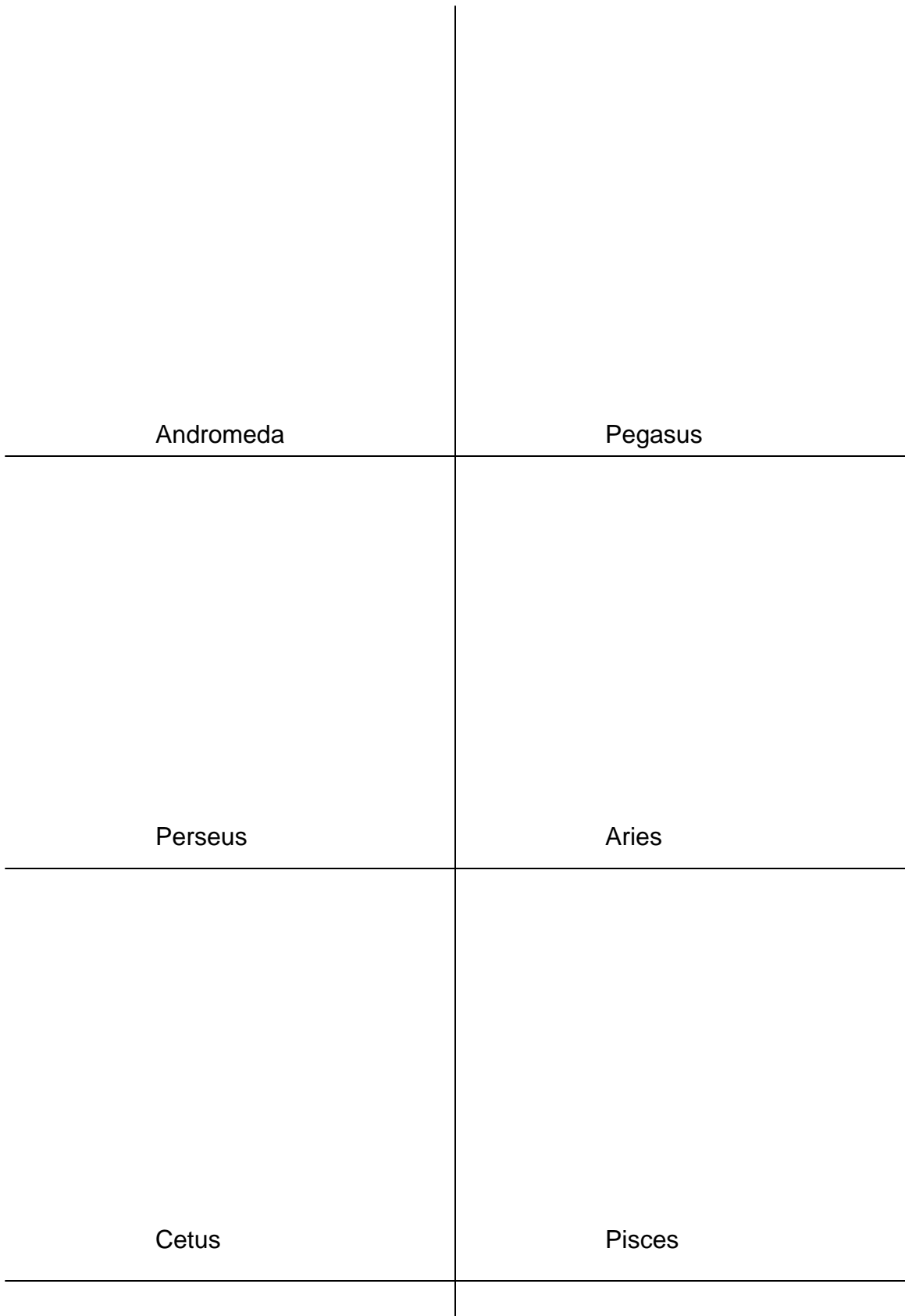
Perseus: To the northeast of Andromeda we find the hero Perseus. Representing the hero who frees Andromeda, he is shown wielding a sword and holding the head of Medusa. In the gorgon's head lies the variable star *Algol*, or "*Ras-al-ghul*", the demon star. Its variability is caused by the mutual eclipse of its two stars once every three days. Sketch Perseus and label *Algol*.

Aries: South of Perseus and Andromeda is the fleece of the golden ram, put in the sky by Zeus after its theft by the hero Jason. Aries is one of the smaller zodiac constellations and although small, consists of several bright stars. The *Pleiades (M45)* cluster of stars lies to its immediate east. Sketch Aries and *M45*.

Cetus: Far to the south of Perseus and Andromeda is the sea monster (or whale), Cetus. Cetus is another very large constellation, although none of its stars are very bright. This was the sea monster that ravaged the Ethiopian coast on the orders of the god Poseidon after his daughters felt insulted by Cassiopeia. The most significant star in Cetus is *Mira*, a variable star that changes its size and brightness with regularity. Ironically, *Mira* was referred to as the "wonderful" star in antiquity, whereas the other nearby variable *Algol* was referred to as the "demon" star. Sketch Cetus and label *Algol*.

Pisces: Between the Great Square of Pegasus and the body of Cetus is another zodiac constellation, Pisces. Fleeing from a primordial monster, Aphrodite and her son Eros attempted to escape by turning themselves into fish & diving into the waters of the Nile River. The fish still have their tails tied together in the night sky. Sketch Pisces.

Autumn Constellations



The Southern Circumpolar Sky

Centaurus: The wise *centaur* Chiron was accidentally poisoned by Hercules. Being immortal, he could not die, so he begged Zeus to remove his agony. Zeus did so, and placed him in the southern sky. Centaurus holds the fourth brightest star of the night sky, *Rigel Kentaurus*, although it is too far to the south to be seen by most northern observers. It is better known as *Alpha Centauri*, and this three-star system is the closest to our own at only 4.3 light years away. Sketch Centaurus and label Rigel Kentaurus.

Cruce: Unlike the northern hemisphere, the south does not currently possess a southern pole star. However, it does have a very distinctive grouping of stars used by navigators in southern waters. The *Southern Cross* stands erect at the moment it rises above the horizon, so its inclination can be used as a natural clock. It is not visible from higher than 25 degrees north latitude. Sketch Cruce.

Carina: South of Canis Major lies Carina, the *ship's keel*. The bright star *Canopus* distinguishes the keel and is second in brightness only to Sirius. The appearance of Canopus signals the beginning of the summer for observers in the southern hemisphere. Observers can see it as far as 37° north latitude. Sketch Carina and label Canopus.

Triangulum Australe: Southeast of Alpha Centauri is the *Southern Triangle*. It is made of average-brightness stars, sometimes said to be the three patriarchs of Hebrew legend. It is invisible to the vast majority of northern observers. Sketch Triangulum Australe.

Pavo: The animal symbol (avatar) of the goddess Hera, the *peacock* also symbolizes immortality by virtue of a tail with jewels fastened to its tail. It lies south of Sagittarius and Scorpius. The most prominent star in Pavo is *Alpha Pavonis*. Sketch Pavo and label Alpha Pavonis.

Octans: The constellation that contains the South Celestial Pole (SCP) is the *octant*. An octant is one of several instruments sailors used several hundred years ago to estimate their location on the open sea by observing the stars. The closest star to the SCP visible to the naked eye is *Sigma Octantis*, a star visible only under very good seeing conditions and (of course) invisible from the northern hemisphere. Sigma Octantis is just over one degree from the SCP, but is so dim that it is not usually referred to as a pole star. Sketch Octans and label Sigma Octantis.

Southern Circumpolar Constellations

