3 Propositional Logic

In this chapter, we study the second system of deduction, Propositional Logic. We are going to learn how to use the truth table to determine the validity of some deductive arguments, whose validity is much more difficult to determine using the system of Categorical Logic. For example, it would feel unnatural to paraphrase the following argument into a categorical syllogism and then decide its validity.

> Either interest rates will be raised or inflation will get worse. Since inflation will get worse, interest rates will be raised.

So instead, we symbolize the argument in a different way to see its logical form. First of all, we use the capital letters "R" and "W" to stand for the sentences "Interest rates will be raised" and "Inflation will get worse." We then use the symbol "∨" for the phrase "Either … or …" and symbolize the first sentence as "$R \vee W$". As a result, we get the following argument form:

$$\begin{array}{l} R \vee W \\ W \\ \hline R \end{array}$$

R: Interest rates will be raised.

W: Inflation will get worse.

To decide whether the argument form is valid, we will learn a formal procedure called the truth table method. By using the method, we can find out that the form is invalid. The argument is therefore not a good argument.

3.1 Symbolization

In Propositional Logic, we use a capital letter to represent a **simple sentence**. Simple sentences are relatively short and do not contain any other sentence as a component. Here are three examples of simple sentences:

> Snow is white.

The sky is blue.

Nancy will go to the party.

We can use the letter "*S*" to symbolize "Snow is white" and "*B*" for "The sky is blue."

In contrast with simple sentences, a sentence like

John will not go to the party.

is a shortened form of the more wordy sentence

It is not the case that John will go to the party.

which contains the simple sentence "John will go to the party" as a clause. Sentences that contain at least one simple sentence as a component are called **compound sentences**.

3.1.1 Five Types of Compound Sentences

To symbolize compound sentences we need to use symbols. There are five different types of compound sentences.

Negations

The sentence

Inflation is not getting worse.

can be rewritten as

It is not the case that inflation is getting worse.

This makes it clear that it is a negation of the simple sentence "Inflation is getting worse." Accordingly, we can symbolize it as $\sim I$. Here the symbol "~" (tilde) stands for "It is not the case that …" and the letter "I" symbolizes the simple sentence "Inflation is getting worse."

Inflation is not getting worse.

$= \sim I$

Notice that there is no space between "~" and "I". The equal sign "=" is used to indicate that the sentence and its symbolization "$\sim I$" are logically equivalent.

Conjunctions

Here is an example of conjunction and its symbolization:

Globalization and free trade are good for business corporations.

= $G \bullet F$

It is easier to see how the symbolization works by expanding the original sentence as

Globalization is good for business corporations and free trade is good for business corporations.

= $G \bullet F$

G: Globalization is good for business corporations.

F: Free trade is good for business corporations.

The letter "G" stands for "Globalization is good for business corporations," and "F" represents "Free trade is good for business corporations." The symbol "•" (dot) is used to symbolize the English connective "and". Notice that there is a space between "G" and "•" and between "•" and "F". Both G and F are called the **conjuncts** of the conjunction. The symbolization is fairly intuitive and there is a one-to-one correspondence to the English sentence.[1]

In the next conjunction,

The cause of schizophrenia is not demonic possession, but defective genes.

= The cause of schizophrenia is not demonic possession, but the cause of schizophrenia is defective genes.

= $\sim P \bullet G$

The letter "P" is used to stand for "The cause of schizophrenia is demonic possession," and "G" for "The cause of schizophrenia is defective genes." Notice that the first conjunct $\sim P$ is a negation.

Disjunctions

In the next example, two simple sentences are connected with the connective "or" to form a disjuction.

The economy will slow down or inflation will get worse.

= $E \vee I$

The letter "E" is used to symbolize "The economy will slow down," and "I" symbolizes "Inflation will get worse." Both E and I are called the **disjuncts** of the disjunction. The symbol "∨" (wedge) is used to symbolize common English connectives such as "or" and "either … or …".

The sentence

It won't rain or snow.

is a negation of a disjunction. We can see this by rewriting it as

It is not the case that it will rain or it will snow.

= $\sim(R \vee S)$

R: It will rain.

S: It will snow.

Conditionals

The most commonly seen conditional sentences are sentences combined together using the phrase "If ..., then ...".

If the worldwide demand for oil continues to grow, then gas prices will keep on rising.

= $D \supset G$

The symbol "⊃" (horseshoe) is used to symbolize the phrase "If ..., then ...".

Biconditionals

Sentences such as

The defendant is guilty if and only if the jury reaches such a verdict.

= $D \equiv J$

are biconditional sentences. The phrase "if and only if" is symbolized using "≡" (triple bar). We will study conditionals and biconditionals in more details later on in this section.

The following table lists the five connectives and the types of compound sentences they are used to form.

Symbols	Names	Compound Statements
~	Tilde	Negation
•	Dot	Conjunction
∨	Wedge	Disjunction
⊃	Horseshoe	Conditional
≡	Triple Bar	Biconditional

3.1.2 The Use of Parentheses

When we symbolize compound statements, it is important to use parentheses properly when they are required. Notice the difference between sentences (3.1a) and (3.1b).

Mike will go to college or find a job, and get married. 3.1a

= $(C \lor J) \bullet M$

Mike will go to college, or find a job and get married. 3.1b

= $C \lor (J \bullet M)$

Without the parentheses, the symbolized expression $C \lor J \bullet M$ amounts to the sentence without the comma ",".

Mike will go to college or find a job and get married.

The sentence is ambiguous because we would not be able to tell whether it means (3.1a) or (3.1b).

Early on, we saw the sentence

It won't rain or snow.

= $\sim(R \lor S)$

Since it is a negation of the disjunction $R \lor S$, we need to put parentheses around the disjunction.

3.1.3 Conditional Sentences

Conditional sentences such as

If it rains, then the ground will be wet.

Interest rates will be raised if inflation gets worse.

are used frequently in Propositional Logic. They have the common form of

If *p*, then *q*.

or

q if *p*.

Here the italic letters "*p*" and "*q*" are used as variables for sentences. Notice that "*q* if *p*" is just another way of writing "If *p*, then *q*."

Symbolizing Conditionals

If p, then q.	=	q if p.	=	$p \supset q$
If p, then q.	=	p only if q.	=	$p \supset q$

By using the above formula, we can see that the following three sentences are simply different ways of writing the same conditional.

If Tim is a football player, then Tim is an athlete.

= Tim is an athlete if Tim is a football player.

= Tim is a football player only if Tim is an athlete.

= $F \supset A$

F: Tim is a football player.

A: Tim is an athlete.

Pay special attention to the difference between the word "if" and the phrase "only if" when they are used in the middle of sentences.

The Sufficient Condition and the Necessary Condition

In a conditional $p \supset q$, p is called the **antecedent**, and q is the **consequent**. The antecedent is a **sufficient condition** for the consequent, and the consequent is a **necessary condition** for the antecedent.

To say that p is a sufficient condition for q means that p is all that is needed for q to be the case.

> p is a sufficient condition for q.
>
> = p is all that is needed for q to be the case.

For example, in the conditional

If it rains, then the ground will be wet.

= $R \supset W$

R: It rains.

W: The ground will be web.

R is a sufficient condition for W. This means that raining is all that is needed for the ground to be wet. In other words, raining alone can make the ground wet. In the next example, If it is a dolphin, then it is a mammal.

Being a dolphin is a sufficient condition for an animal being a mammal.

If *p* is a sufficient condition for *q*, then this also means that *q* is a necessary condition for *p*. So being a mammal is a necessary condition for being a dolphin. That is, without being a mammal, an animal cannot be a dolphin.

> *q* is a necessary condition for *p*.
> = Without *q*, it cannot be the case that *p*.

In 1.3, we learn about certain concepts such as validity and soundness used in argument evaluation. For a deductive argument to be sound, it needs to be valid and have true/acceptable premises. So if a deductive argument is not valid, it cannot be sound. This means that being a valid argument is a necessary condition for being a sound argument.

In the sentence

Tim will go camping if it does not rain or snow.

= $\sim(R \vee S) \supset C$

The negation $\sim(R \vee S)$ is the antecedent. This means that a sufficient condition for Tim to go camping is that it does not rain or snow.

Biconditionals

The following sentence is a biconditional sentence and is symbolized with the connective "≡" (triple bar).

Maria will receive a pay raise if and only if she gets the TV commercial account. 3.1c

= $P \equiv A$

P: Maria will receive a pay raise.

A: Maria gets the TV commercial account.

A biconditional is really a conjunction of two conditionals. The connective "≡" typically stands for the English phrase " … if and only if …". The formula

p if and only if *q*

is an abbreviation for

(*p* if *q*) and (*p* only if *q*)

= $(q \supset p)$ and $(p \supset q)$.

Fully symbolized, it becomes

$$(q \supset p) \bullet (p \supset q)$$

Now in the first conditional $q \supset p$, q is the antecedent. This means that q is a sufficient condition for p. In the second condition $p \supset q$, q is the consequent, and hence is a necessary condition for p. The two conditionals together says that q is both a sufficient condition and a necessary condition for p.

Moreover, since

$(q \supset p)$ and $(p \supset q)$

is logically equivalent to

$(p \supset q)$ and $(q \supset p)$

this means that p is also both a sufficient condition and a necessary condition for q.

In the example we just saw

Maria will receive a pay raise if and only if she gets the TV commercial account. 3.1c

= $P \equiv A$

P: Maria will receive a pay raise.

A: Maria gets the TV commercial account.

Maria's getting the TV commercial account is *both a sufficient condition and a necessary condition* for her receiving a pay raise. This means that getting the account is the only thing she needs to do to receive a pay raise. Moreover, without getting the account, she won't receive a pay raise. That is, getting the account is also the only way she can receive a pay raise:

getting the account	→	receiving a pay raise
not getting the account	→	not receiving a pay raise

Compare (3.1c) with the next example:

Maria will receive a pay raise *if* she gets the TV commercial account. 3.1d

= $A \supset P$

P: Maria will receive a pay raise.

A: Maria gets the TV commercial account.

The conditional says that Maria's getting the TV commercial account is a *sufficient* condition for her receiving a pay raise. This means that all she needs to do to receive a pay raise is to get the account. Notice the conditional does not say that getting the account is a necessary condition for the pay raise. So it leaves it open whether Maria will receive a pay raise if she does not get the account. This means that it is possible for Maria to receive a pay raise even though she fails to land the account. One possible scenario is that Maria does not get the account, but manages to sell the commercial to another company and as a result receives a pay raise.

getting the account	→	receiving a pay raise
not getting the account	→	may or may not receive a pay raise

The important difference between (3.1c) and (3.1d) is that (3.1c) specifically says that getting the account is required (that is, a necessary condition) for Maria to receive a pay raise whereas (3.1d) does not say that it is required. This makes (3.1d) less demanding than (3.1c). Now compare the above two examples with another one:

Maria will receive a pay raise *only if* she gets the TV commercial account. 3.1e

$= P \supset A$

P: Maria will receive a pay raise.

A: Maria gets the TV commercial account.

The sentence (3.1e) says that Maria's getting the TV commercial account is a *necessary* condition for her receiving a pay raise. This means that without getting the account, she won't receive a pay raise. But (3.1e) does not specify that getting the account is a sufficient condition for receiving a pay raise. So Maria may or may not receive a pay raise even if she does get the account.

getting the account	→	may or may not receive a pay raise
not getting the account	→	not receiving a pay raise

It is important to notice the differences among the three examples here. The specification of condition(s) makes (3.1d) the best deal among the three for Maria, and (3.1e) the least favorable.

3.1.4 Exclusive vs. Nonexclusive Disjunctions

The connectives "or" and "either … or" are used in two distinct ways in daily discourses. When a host asks you "Coffee or Tea?", it is implicitly implied that you should choose coffee or tea, but not both. The connective "or" is used in the **exclusive** sense to mean "one or the other, but not both." Afterwards, when the host asks you again "Cream or sugar?", you can respond by saying "Both, please." Now the connective is used in the **nonexclusive** sense of "one or the other, or both."

Here is an example of "either … or …" used in the nonexclusive sense:

Either fire or smoke can damage the paintings. 3.1f

= $F \vee S$

F: Fire can damage the paintings.

S: Smoke can damage the paintings.

If either fire or smoke alone can damage the paintings, then the two together can damage the paintings. In Propositional Logic, the wedge "∨" is used to symbolize nonexclusive disjunctions. So the sentence (3.1f) is symbolized as $F \vee S$. By contrast, in the next sentence "either ... or ..." is used in the exclusive sense.

The Federal Reserve will either raise interest rates or leave them intact. 3.1g

= $(R \vee L) \bullet \sim(R \bullet L)$

R: The Federal Reserve will raise interest rates.

L: The Federal Reserve will leave interest rates intact.

Obviously the Federal Reserve cannot both raise interest rates and keep them intact. Consequently, we have to symbolize (3.1g) as $(R \vee L) \bullet \sim(R \bullet L)$. The first conjunct $R \vee L$ means that the Federal Reserve will do one or the other, or both. But the second conjunct $\sim(R \bullet L)$ says that the Federal Reserve will not do both. So together, they capture the meaning of "one or the other, but not both."

How to Symbolize "unless"

A compound sentence formed with the connective "unless" can be symbolized as a conditional or a biconditional, depending on the meaning of the sentence. It can also be symbolized as a disjunction. But in doing so, we need to pay attention to whether it is the exclusive or the nonexclusive disjunction. The sentence

Jeff cannot graduate unless he completes all the GE requirements. 3.1h

states clearly that fulfilling the GE requirements is a necessary condition for Jeff to graduate. That is, without fulfilling the GE requirement, Jeff cannot graduate. So we can rewrite (3.1h) as

Jeff can graduate only if he completes all the GE requirements. 3.1i

= $G \supset C$

G: Jeff can graduate.

C: Jeff completes all the GE requirements.

The sentence (3.1i) is also logically equivalent to

3.1j

If Jeff does not complete all the GE requirements, then he cannot graduate.

= $\sim C \supset \sim G$

G: Jeff can graduate.

C: Jeff completes all the GE requirements.

We can also rewrite (3.1h) as

Either Jeff completes all the GE requirements or he cannot graduate. 3.1k

= $C \lor \sim G$

Notice (3.1k) is symbolized as a nonexclusive disjunction $C \lor \sim G$, because it is possible that Jeff completes all the GE requirements but still cannot graduate due to, say, having not yet met the total unit requirement.

Since $p \lor q$ is logically equivalent to $q \lor p$, now if we let $p = C$ and $q = \sim G$, then we can see clearly that $C \lor \sim G$ is logically equivalent to $\sim G \lor C$. As a result, we can symbolize (3.1h) as $\sim G \lor C$.

Jeff cannot graduate unless he completes all the GE requirements. 3.1h

= $\sim G \lor C$

This shows us that we can symbolize "unless" in the nonexclusive sense with the symbol "∨". Now compare (3.1h) with the next sentence:

Mike will remain single unless he marries Katie. 3.1l

= $S \equiv \sim K$

S: Mike will remain single.

K: Mike marries Katie.

(3.1l) means that if Mike does not marry Katie, then he will remain single, and if he marries Katie, he would not remain single. (The second conditional is normally left unstated because there is no need to say the obvious.) The two conditionals together say that marrying Katie is both a sufficient condition and a necessary condition for Mike's not staying single. So we can rewrite it as

Mike will remain single if and only if he does not marry Katie. 3.1m

= $S \equiv \sim K$

S: Mike will remain single.

K: Mike marries Katie.

The example shows that we can symbolize "unless" in the exclusive sense with the triple bar "≡" and the tilde "~".

3.1.5 “Not … both …” and “Both … not …”

It is important not to conflate “Not … both …” and “Both … not …”. Compare these two sentences:

Not both Monet and Chopin are painters. 3.1n

= It is not the case that Monet is a painter and Chopin is a painter.

= $\sim(M \bullet C)$

M: Monet is a painter.

C: Chopin is a painter.

Both Dvořák and Schubert are not painters. 3.1o

= Dvořák is not a painter and Schubert is not a painter.

= $\sim D \bullet \sim S$

D: Dvořák is a painter.

S: Schubert is a painter.

The sentence (3.1n) denies that both Monet and Chopin are painters. That is, it says that at least one of them is not a painter. It can be rephrased as

Either Monet or Chopin is not a painter. 3.1p

= Either Monet is not a painter or Chopin is not a painter.

= $\sim M \vee \sim C$

It is probably easier to see why (3.1p) is symbolized as $\sim M \vee \sim C$ if we expand it fully as

Either Monet is not a painter or Chopin is not a painter.

Since (3.1n) and (3.1p) are logically equivalent, we have $\sim(M \bullet C) = \sim M \vee \sim C$.

By contrast, the sentence (3.1o) is a conjunctin.

Both Dvořák and Schubert are not painters. 3.1o

= Dvořák is not a painter and Schubert is not a painter.

= $\sim D \bullet \sim S$

D: Dvořák is a painter.

S: Schubert is a painter.

Moreover, (3.1o) is logically equivalent to both sentences below:

Not either Dvořák or Schubert is a painter. 3.1q

= It is not the case that either Dvořák is a painter or Schubert is a painter.

= $\sim(D \lor S)$

Neither Dvořák nor Schubert is a painter. 3.1r

= It is not the case that either Dvořák is a painter or Schubert is a painter.

= $\sim(D \lor S)$

Both (3.1q) and (3.1r) deny that at least one of them is a painter. So $\sim D \bullet \sim S$ is logically equivalent to $\sim(D \lor S)$.

The following formulas sum up the differences between "Not ... both ..." and "Both ... not ..." and show how to symbolize them:

Not both p and q	= $\sim(p \bullet q)$
= Either $\sim p$ or $\sim q$	= $\sim p \lor \sim q$

Both $\sim p$ and $\sim q$	= $\sim p \bullet \sim q$
= Not either p or q	= $\sim(p \lor q)$
= Neither p nor q	= $\sim(p \lor q)$

As a matter of fact, these two formulas are called **De Morgan's laws** in logic.

Exercise 3.1

I. Symbolize the following sentences using the five logical connectives and the capital letters provided.

1. Nancy won't come to the party. (N)

~ • ∨ ⊃ ≡ Check Answers

2. Nancy and Jeff will come to the party. (N, J)

~ • ∨ ⊃ ≡ Check Answers

3. Nancy and Jeff won’t come to the party. (N, J)

~ • ∨ ⊃ ≡ Check Answers

4. Nancy or Jeff will come to the party. (N, J)

~ • ∨ ⊃ ≡ Check Answers

5. Nancy or Jeff won’t come to the party. (N, J)

~ • ∨ ⊃ ≡ Check Answers

6. Nancy will come to the party, but Jeff won’t. (N, J)

~ • ∨ ⊃ ≡ Check Answers

7. Nancy won’t come to the party, but Jeff will. (N, J)

~ • ∨ ⊃ ≡ Check Answers

8. If Nancy is invited, then Jeff will come to the party. (N, J)

~ • ∨ ⊃ ≡ Check Answers

9. Jeff will come to the party if Nancy is invited. (J, N)

~ • ∨ ⊃ ≡ Check Answers

10. Jeff will come to the party only if Nancy is invited. (J, N)

~ • ∨ ⊃ ≡ Check Answers

11. Jeff will come to the party if and only if Nancy is invited. (J, N)

~ • ∨ ⊃ ≡ Check Answers

12. Jeff will not come to the party if Nancy is invited. (J, N)

~ • ∨ ⊃ ≡ Check Answers

13. Jeff will come to the party only if Nancy is not invited. (J, N)

~ • ∨ ⊃ ≡ Check Answers

14. Jeff will come to the party if and only if Nancy is not invited. (J, N)

~ • ∨ ⊃ ≡ Check Answers

15. Jeff will not come to the party if both Kathy and Nancy are invited. (J, K, N)

~ • ∨ ⊃ ≡ Check Answers

16. Jeff will not come to the party if both Kathy and Nancy are not invited. (J, K, N)

~ • ∨ ⊃ ≡ Check Answers

17. If Nancy is not invited, then Jeff will not come to the party but Bill will. (N, J, B)

~ • ∨ ⊃ ≡ Check Answers

18. Jeff will come to the party only if Nancy is invited but Bill isn’t. (J, N, B)

~ • ∨ ⊃ ≡ Check Answers

19. Both Emma and Jessica are married. (E, J)

~ • ∨ ⊃ ≡ Check Answers

20. Both Emma and Jessica are not married. (E, J)

~ • ∨ ⊃ ≡ Check Answers

21. Emma is not married, but Jessica is. (E, J)

~ • ∨ ⊃ ≡ Check Answers

22. Either Emma or Jessica is married. (E, J)

~ • ∨ ⊃ ≡ Check Answers

23. Either Emma or Jessica is not married. (E, J)

~ • ∨ ⊃ ≡ Check Answers

24. Not both Emma and Jessica are married. (E, J)

~ • ∨ ⊃ ≡ Check Answers

25. Not either Emma or Jessica is married. (E, J)

~ • ∨ ⊃ ≡ Check Answers

26. Neither Emma nor Jessica is married. (E, J)

~ • ∨ ⊃ ≡ Check Answers

27. Chris will take logic or psychology. (L, P)

~ • ∨ ⊃ ≡ Check Answers

28. Chris will take logic and psychology. (L, P)

~ • ∨ ⊃ ≡ Check Answers

29. Chris won’t take logic or psychology. (L, P)

~ • ∨ ⊃ ≡ Check Answers

30. Chris won’t take logic and psychology. (L, P)

~ • ∨ ⊃ ≡ Check Answers

31. Thea will choose economics or sociology as her major. (E, S)

~ • ∨ ⊃ ≡ Check Answers

32. Thea will choose economics as her major unless she picks sociology. (E, S)

~ • ∨ ⊃ ≡ Check Answers

33. Rachel does not like Jazz and classical music. (J, C)

~ • ∨ ⊃ ≡ Check Answers

34. Rachel does not like Jazz or classical music. (J, C)

~ • ∨ ⊃ ≡ Check Answers

35. Mike can graduate from college if he completes all the GE requirements. (G, R)

~ • ∨ ⊃ ≡ Check Answers

36. Mike can graduate from college only if he completes all the GE requirements. (G, R)

~ • ∨ ⊃ ≡ Check Answers

37. Mike cannot graduate from college unless he completes all the GE requirements. (G, R)

~ • ∨ ⊃ ≡ Check Answers

38. Mike can graduate from college unless he does not complete all the GE requirements. (G, R)

~ • ∨ ⊃ ≡ Check Answers

39. José won't buy a Ford truck if he buys a Toyota. (F, T)

~ • ∨ ⊃ ≡ Check Answers

40. José will buy a Ford truck only if he does not buy a Toyota. (F, T)

~ • ∨ ⊃ ≡ Check Answers

41. José will buy a Ford truck unless he buys a Toyota. (F, T)

~ • ∨ ⊃ ≡ Check Answers

42. If it does not rain or snow, then the Taylors will go camping. (R, S, C)

~ • ∨ ⊃ ≡ Check Answers

43. If it rains or snows, then the Taylors won't go camping. (R, S, C)

~ • ∨ ⊃ ≡ Check Answers

44. The Taylors will go camping only if it does not rain or snow. (C, R, S)

~ • ∨ ⊃ ≡ Check Answers

45. The Taylors will go camping unless it rains or snows. (C, R, S)

~ • ∨ ⊃ ≡ Check Answers

46. If inflation is under control and the economy is slowing down, then interest rates will be lowered. (U, S, L)

~ • ∨ ⊃ ≡ Check Answers

47. The economy will slow down unless consumer confidence stays high and inflation is under control. (S, H, U)

~ • ∨ ⊃ ≡ Check Answers

48. The economy will slow down unless interest rates are lowered, but if interest rates are lowered, inflation will get worse. (S, L, W)

~ • ∨ ⊃ ≡ Check Answers

49. Without campaign finance reform people would not have equal access to political power. (C, E)

~ • ∨ ⊃ ≡ Check Answers

50. Organic foods are neither safer nor more nutritious than non-organic foods. (S, N)

~ • ∨ ⊃ ≡ Check Answers

51. Both solar power and wind power are not practical solutions to the current energy crisis. (S, W)

~ • ∨ ⊃ ≡ Check Answers

52. Not both environmentalists and business developers are happy with the new city plan. (E, B)

~ • ∨ ⊃ ≡ Check Answers

53. Genetic modification is morally acceptable only when it is used to prevent genetic disorders. (M, P)

~ • ∨ ⊃ ≡ Check Answers

54. Parents would want designer babies provided that they are obsessed with giving their kids head starts. (D, H)

~ • ∨ ⊃ ≡ Check Answers

55. Socioeconomic equality cannot be achieved as long as people are free to accumulate wealth. (E, F)

~ • ∨ ⊃ ≡ Check Answers

56. We have to reduce the national debts or cut taxes to stimulate further economic growth. (R, C, S)

~ • ∨ ⊃ ≡ Check Answers

57. The federal budget cannot be balanced unless taxes are raised and government spending is cut. (B, R, C)

~ • ∨ ⊃ ≡ Check Answers

58. Workers would not have job security if more manufacturing relies on robotic automation and the globalization of the labor market continues. (J, R, G)

~ • ∨ ⊃ ≡ Check Answers

59. Nations won't fight over natural resources only if people cut back consumption and new technologies provide alternative energy sources. (F, C, T)

~ • ∨ ⊃ ≡ Check Answers

60. If we do not change the culture of bullying and prevent youngsters from acquiring guns, then there will be more school shootings. (B, G, S)

~ • ∨ ⊃ ≡ Check Answers

II. Use the concepts of the sufficient condition and the necessary condition to decide whether the inferences are correct.

1. Suppose Nick's mother tells Nick that he can play video games only after he finishes his homework. This means that Nick is entitled to play video games after he finishes his homework.

2. Ryan needs to pass the exit examination to graduate from high school. If we find out that Ryan has passed the test, then we know that he can graduate.

3. Ashley will buy a new car if she is promoted to the manager position. After learning that she gets the promotion we can infer that she will buy a new car.

4. The Miller family will buy a house unless their offer is rejected. The house owner accepts their offer. So they are going to buy the house.

5. A reasonable person cannot be closed-minded. From the fact that a person is open-minded it follows that she or he is reasonable.

6. Lowering interest rates can boost the stock market. Upon learning that the Federal Reserve just lowered the interest rates, we can be confident that the stock market will go up.

7. We learn from Alzheimer's disease that memory requires a healthy and functional brain. This means that without a brain, we would not have memory.

8. A college degree has increasingly become a required qualification for a good-pay job. So by making college education affordable and accessible we can achieve economic equality.

9. Many moral philosophers maintain that we are morally responsible for our actions because we have free will. So if our free will is curtailed under certain circumstances, then we would be less morally responsible in such situations.

10. Without stem cell researches, it would be much harder and take longer time to find cures for many diseases. So if we want good progress in finding cures, we need to permit and fund stem cell researches.

11. Reducing the number of migrant workers would lead to labor shortage or higher labor cost, which would in turn cause higher consumer price index and weaken the economy. So to keep the economy strong, we need to find a way to accommodate migrant workers.

12. There is no religious freedom if we have a state religion. This is why the separation of church and state is essential for freedom of religion.

* * *

[1]In Propositional Logic, a capital letter without quotation marks represents a simple statement. When we want to talk about the letter itself, we put quotation marks around the letter. Following this convention, we would say that "*B*" is the second letter in the symbolization "*A* • *B*". By contrast, we would say that *B* is the second conjunct in the conjunction *A* • *B*. This is important because it would be a mistake to say that "*B*" is the second conjunct in the conjunction *A* • *B*.

Following the same convention, we say "T" and "F" are two capital letters, but T (truth) and F (falsity) are two possible truth values of a statement in Propositional Logic.

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