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IN THE SERVICE OF GOOD WRITING

If I Were King of the Forest…! — The Grammar, Meaning, and Logic of Conditional Statements

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ABSTRACT

This article provides a basic overview of the grammar of conditionals, the role of conditionality in predicate logic, and the difference between conditionality and causality. Medical writers must achieve mastery of these concepts, which are important not just for clear writing but for rational thinking. English speakers use conditionals for many different purposes, such as describing facts, habits, and rules (zero-order conditionals); describing the future consequences of realistic, possible, or likely events (first-order conditionals); expressing the likely consequence of some uncertain or impossible event (second-order conditionals); or talking about how things could have turned out differently if some condition had been met in the past (third-order conditionals). Conditionals also allow one to ask questions about the consequences of an event or to express the conditions under which a command should be followed. Conditional constructions are also sometimes used in expressions that don't really express conditions (relevance conditionals). The grammatical differences between these expressions are subtle, involving the tense and mood of the verbs. Conditionals allow you to talk about how the truth-values of different propositions are interrelated. Thus, once you master the grammar of conditionals, you can begin to learn the rules and pitfalls of deductive and inductive reasoning. In science, such reasoning is often the first step toward proving causality. The existence of a tight correlation between two phenomena does not prove that one causes the other, but the lack of a correlation suggests that a causal relationship is unlikely.

A conditional statement is a way to say that the truth of one statement depends on the truth of some other statement. A conditional statement contains 2 clauses: an *if*-clause (also known as the *antecedent* or *protasis*) and a main clause (also known as the *consequent* or *apodosis*). In the movie *The Wizard of Oz*, the Cowardly Lion sings, "If I were king of the forest…" He then describes what he and others would do. Of course, because he is cowardly, he does not rule the forest, and nobody does any of those things.

Conditional statements can do something that seems like alchemy: they can combine 2 false statements and turn them into a truth. That's because the truth of the conditional statement depends not on the truth value (truth or falsity) of either of its clauses but on the relationship between the truth values of the 2 clauses. In each conditional statement that the Cowardly Lion makes, both the *if*-clause and the main clause contain a statement that is false. Yet, the conditional statement that he makes by putting those false statements together is true because if the antecedent were true, the consequent would also be true: if he did rule the forest, others would respect him.

The grammatical rules for making conditional statements in English are simple, yet conditionality is a complicated subject that has been an active area of research in linguistics, philosophy, and cognitive science. As medical writers, we need to pay attention to 3 basic issues related to conditionality:

- Intelligibility—Is the conditional statement grammatical and meaningful?
- Linguistic modality—Does the antecedent contain a statement that is definitely true, possibly true, or utterly impossible? Is the consequent a statement of fact, a suggestion of what might be possible, a command, a threat, or something else entirely?
- The relationships between the statements—How tight is the relationship of the truth values of statements in the antecedent and consequent? Does this relationship reflect some underlying cause-and-effect (causal) relationship? Are these 2 statements not telling the whole story?

As medical writers, we often need to express what is always true, what is generally or occasionally true, and what is true only under certain conditions. We must also grapple with questions of cause and effect and warn people about possible consequences. In English, we can use conditional

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statements to describe statistical and causal relationships, establish rules, make promises and threats, issue warnings, or even just express our feelings. Yet all these different kinds of expressions have similar grammatical forms. Unlike some languages, such as Spanish, English does not use word endings to mark the conditional mood of verbs. Nevertheless, there are grammatical rules that you need to follow when making conditional statements. This article explains the rules, as well as how conditional statements can be used to express all these relationships.

STRUCTURE OF CONDITIONAL STATEMENTS

All conditional statements include at least 2 clauses, one independent and the other dependent. A *clause* is a word string that contains a subject and a predicate. The consequent of a conditional sentence is an independent clause because it can stand on its own as a sentence. In contrast, the antecedent is a dependent clause (ie, it cannot stand on its own as a sentence) because it is introduced by a subordinating conjunction—usually "if" but sometimes other words, such as "when" or "unless":

> If I were king of the forest…!

This *if*-clause (antecedent) acts as an adverb that modifies the rest of the sentence. The antecedent expresses limiting conditions for the main clause of the sentence, whether that main clause is a statement or a command.

The word *antecedent* comes from the Latin for "to go before." However, the antecedent of a conditional statement does not have to be at the beginning of the sentence. If the antecedent is at the beginning of a sentence, set it off with a comma; but don't use a comma to set off an antecedent that follows the main clause.

- If I were you, I would not do that.
- I would not do that if I were you.

Sometimes, the subordinating conjunction "then" is used to mark the consequent of the conditional statement, but it is optional:

> If the light is green, [then] you can go.

Note that the clauses within a conditional statement can be compound (ie, they contain more than one independent clause):

> When it is warm outside and the sun is shining, I ride my bicycle and she goes swimming.

TYPES OF CONDITIONAL STATEMENTS

There are 5 basic kinds of conditional statements. Each serves a different purpose (or set of purposes) and follows a different set of grammatical rules in English.

Zero-Order Conditionals

A *zero-order conditional* is used to describe facts, habits, and rules. The verbs in the antecedent and consequent are often in the simple present tense. Because the zero-order conditional expresses something that is always true, as long as the conditions are met, the timing does not matter and may go unspecified. In fact, the consequent may describe an event that happens before the event described in the antecedent, even though the word *antecedent* means "that which goes before" and *consequent* means "that which follows."

- If the solution is alkaline, the litmus paper turns blue.
- Whenever she leaves the house, she takes her cellphone.
- If the patient is allergic to penicillin, a macrolide antibiotic is used.

Zero-order conditionals have been described as indicative conditionals (the indicative mood is used for expressing facts and truth). However, the clauses contained within the antecedent and consequent are not statements of fact. For example, the *if*-clause is not saying that there *is* a patient who is allergic to penicillin. Also, if nobody has a penicillin allergy, then it's possible that nobody will get the macrolide. Thus, the verbs in the antecedent and consequent of an indicative conditional are not expressing a realis modality. As I explained in an earlier installment of this column,"[1] *realis modalities*, such as the indicative mood in English, are used for expressing facts and truth. *Irrealis modalities* are used for expressing other things, such as questions, commands, the antecedents and consequents of conditional statements, and statements that are contrary to fact. Nevertheless, the conditional statement, taken as a whole, can be a statement of fact. A fact is not the same thing as a statement of fact; a fact is something that makes a statement of fact true or false. For example, if I state that there is a piano in my living room, the existence of the piano in my living room is the fact that makes my statement true. A conditional statement can be true if the facts support it.

Even though zero-order conditionals are called indicative conditionals, the consequent might not express something that is always true every single time the antecedent is true. It might instead express what is typically or often true. To clarify how tight the relationship between antecedent and consequent are, you can use adverbs such as "always,"

"usually," "generally," "sometimes," or "occasionally" in the consequent.

> If you call her during business hours, she usually answers.

For zero-order conditionals, the words "when" and "whenever" can be substituted for "if."

> She takes her cellphone whenever she leaves the house.

The clauses in a conditional statement can also take a negative form:

> If the sun is not shining, the solar oven does not work.

If the consequent is always true whenever the antecedent is true, the antecedent is considered a sufficient condition for the consequent:

> If patients with scurvy get vitamin C, they recover.

Of course, in medicine, the outcome of any case is going to depend on many factors, some of which go unstated and possibly unnoticed. As Shakespeare's *Hamlet* put it, "There are more things in heaven and earth, Horatio, than are dreamt of in your philosophy."[2] Thus, it goes without saying that a patient who has had major bleeding from scurvy might need a blood transfusion, in addition to vitamin C. If, on the other hand, the antecedent must be true for the consequent to be true, then the antecedent is a necessary condition for the consequent. A necessary condition can be expressed by the inverse of the conditional, which negates both the antecedent and the consequent of the original conditional statement:

> If patients with scurvy don't get vitamin C, they don't recover.

The inverse of a conditional statement can be phrased with "unless they do" instead of "if they do not":

> Unless they get vitamin C, patients with scurvy don't recover.

You can also use "only if" to express a necessary condition:

> Patients with scurvy recover only if they get vitamin C.

Although a necessary condition must be present for the consequent to occur, the consequent might not occur even if the necessary condition is present. So, although it is generally true that people recover from scurvy if they get vitamin C, they might not recover if the vitamin C is given too late.

If an antecedent is both necessary and sufficient for the consequent to be true, the statement is biconditional. A *biconditional statement* is true when its antecedent and consequent always have the same truth value (ie, both true or both false). Biconditional statements can be phrased with "if and only if":

> Patients with scurvy recover if and only if they get vitamin C.

First-Order Conditionals

First-order conditional statements are used to describe the consequences of realistic, likely, or possible events. Even though the *if*-clause generally refers to something that has not yet happened, its verb is in the present tense, whereas the consequent uses the future tense.

First-order conditionals are often used in negotiations.

> If you finish the work early, I will give you a bonus.

First-order conditionals can also be used to issue threats and warnings and to express superstitions. Note that in those cases, the event described in the main clause might not happen, even if the condition in the *if*-clause is met:

- If you hit me, I will hit you back.
- If you don't control your blood sugar, you will have serious complications.
- If you break a mirror, you will have 7 years of bad luck.

Second-Order Conditionals

Second-order conditionals can be used to express hypothetical conditionals. Hypothetical means founded on an idea that has not been verified as true. To emphasize the uncertainty or impossibility of the hypothetical antecedent, its verb is in the subjunctive mood, which follows the same conjugation as the indicative past tense in English. That's why the verb sounds as if it is in the past tense, even when it is describing something that could happen in the future.

A second-order conditional can be used to express a future event that would happen if some unlikely hypothetical event were to occur:

- If I won the lottery, I would buy a fancy new car.
- If I were to start training today, I would be ready to run a marathon by next summer.

You can also phrase the second-order conditional without an "if," but then you would have to switch the order of the subject and verb:

> Were we to give up this fight, it would mean the end of democracy.

A second-order conditional can also be used to express what would be happening now if things were different. These statements are *counterfactual conditionals* because the condition described in the antecedent is contrary to fact:

> If wishes were horses, then beggars would ride.

Third-Order Conditionals

A *third-order conditional* is also counterfactual because it deals with conditions that were not met. It explains what would have happened in the past had the condition been met. The verb in the *if*-clause is in the past-perfect tense, and the verb in the main clause uses "would have" and the past participle.

> If I had known that you were coming, I would have baked you a cake.

Mixed Conditionals

There are 3 basic kinds of mixed conditionals. They all deal with counterfactual statements in the *if*-clause and the main clause. One deals with the consequences in the present if something different had happened in the past. The verb in the *if*-clause is in the past perfect, and the modal auxiliary "would" is used in the main clause:

> If Julie had scored higher on her MCAT, she would be in medical school today.

Another mixed conditional deals with what would happen in the future if something in the past had been different. The past perfect is used in the *if*-clause, and the auxiliary "would" is used along with some expression of the future. Sometimes, "would be" and the present participle are used, or "would" and the bare infinitive, plus some adverb or adverbial phrase to indicate a future timeframe.

- If she had booked the flight earlier, she would be going with us on Wednesday.
- If she hadn't forgotten to book the flight, she would go with us on Wednesday.

Another mixed conditional deals with a counterfactual *if*-clause in which the present tense is used to express a general fact or truth, and a main clause that talks about the past:

> If I were rich, I would have given you the money.

Other Conditionals

In a conditional question, the antecedent acts as a modifier to the question asked in the consequent:

> What do we do if the patient is allergic to penicillin?

In a conditional imperative, the antecedent modifies a command that is given in the consequent:

> If you think that someone is having a stroke, call an ambulance immediately.

There are also many statements that are phrased as conditionals, even though the truth value of the consequent has nothing to do with the truth value of the antecedent. These are sometimes called *relevance conditionals* or "biscuit conditionals":

- There are biscuits in the pantry, if you want some. (The biscuits are there, whether you want them or not.)
- If you ask me, she's out of her mind.

The phrase "if only" can also be used idiomatically to express a wish:

> If only it would stop raining!

THE LOGIC OF CONDITIONALS

When we study conditionals, we set foot on the bridge that connects grammar to logic. We have to think about how the truth values of the clauses within a conditional sentence relate to the truth value of the conditional sentence as a whole. We can then incorporate that conditional sentence into a logical argument, which may reveal other truths.

Conditional Statement

Logicians often use capital letters, such as P and Q, to stand for propositions. A proposition is a statement that can be true or false. The word *proposition* comes from the Latin for "something put forth." A proposition can be a supposition: something that you accept as true for the purposes of an argument. Grammatically, a proposition has a subject and a predicate whose verb is in the indicative mood. Logicians often use T and F to stand for "true" and "false" and a right-

ward-pointing arrow to indicate an if-then relationship. So, P→Q means "if proposition P is true, then proposition Q is true." (Note that the conditional statement P→Q is also a proposition because it can be true or false.) The table shows the possible truth values of P and Q, and the effect that these truth values would have on the truth of the various conditional statements involving P and Q. Note that P→Q is false *only* when Q is false while P is true. (This relationship holds when P→Q is a hard rule that allows for no exceptions.)

Inverse Statement

Logicians often use a tilde (~) to indicate negation. To form the inverse of a conditional statement, you negate both the antecedent and the consequent.

- Conditional: If I am king of the forest, I get respect. (P→Q)
- Inverse: If I am not king of the forest, I don't get respect. (~P→~Q)

Note also that the negation of a negative statement is a positive statement:

- Negative statement: There are no cookies in the jar.
- Negation of negative statement: There are cookies in the jar.

A conditional statement can be true while its inverse is false, and vice versa (ie, even a person who is not king of the forest can be respected) (Table).

Contrapositive Statement

To form the contrapositive of a conditional statement, you negate both propositions and switch the positions of the antecedent and consequent.

- Conditional: If I am king of the forest, I get respect. (P→Q)
- Contrapositive: If I do not get respect, then I am not king of the forest. (~Q→~P)

A conditional statement and its contrapositive are logically equivalent to each other (ie, they always have the same truth value) (Table). Thus, you can prove that a conditional statement is true by proving that its contrapositive is true, and vice versa.

Converse Statements

The converse of a conditional statement is made by switching the clauses.

- Conditional: If I am king of the forest, I get respect (P→Q)
- Converse: If I get respect, I am king of the forest (Q→P)

A conditional and its converse do *not* always have the same truth value (Table). Lots of people who get respect are not king of the forest. The converse and the inverse of a conditional statement are logically equivalent to each other (ie, they always have the same truth value) (Table).

Biconditional Statements

As described above, a biconditional statement is a way of saying that both a conditional (P→Q) and its converse (Q→P) have the same truth value (Table). Either they are both true, or they are both false. A biconditional statement can be expressed with a double arrow: P↔Q. Writers can express biconditionality by saying the conditional statement and adding "and conversely." Writers can also express biconditionality by saying "if and only if." Logicians sometimes abbreviate that to *iff*.

Valid and Strong Arguments

Logic is the study of how statements can be combined into arguments. For example, you could assert that both "If P, then Q" and "P" are true. You can then use those propositions as premises to support the conclusion that Q must therefore be true. The premises of an argument are *if*-statements, and the conclusion is a *then*-statement. The ∴ symbol is used as a conclusion marker. It can be translated as "therefore."

P→Q
P
∴Q

Table. Truth Table

Antecedent	Consequent	Conditional	Inverse	Contrapositive	Converse	Biconditional
P	Q	P→Q	~P→~Q	~Q→~P	Q→P	Q↔P
T	T	T	T	T	T	T
T	F	F	T	F	T	F
F	T	T	F	T	F	F
F	F	T	T	T	T	T

→, if-then; ~, not, ↔, if and only if.

In logic, an argument is valid if its conclusion must be true whenever all of its premises are true. If an argument is valid and its premises are all true, then it is sound. Its conclusion will therefore be true. There are 2 important valid arguments that relate to conditionals:

- Modus ponens—If P→Q is true, and P is true, then Q is also true. "Modus ponendo ponens" is Latin for "the method of placing by placing."
- Modus tollens—If P→Q is true, but Q is false, then P is also false. "Modus tollendo tollens" is Latin for "the method of removing by removing."

Formal Fallacies

A logical fallacy is an error in reasoning that may lead you to draw a false conclusion, even if your premises are true. Formal fallacies are logical fallacies that result from the improper form of the argument. Informal fallacies can result from other problems, such as a misunderstanding of the meaning of the words involved. The following formal fallacies arise from a misunderstanding of how conditional statements work:

- Affirming the consequent—If you know that P→Q is true, and Q is true, but then conclude that P must therefore also be true, you have made an error called affirming the consequent (Q being the consequent). This error is also called the converse error (Q→P is the converse of P→Q), or the confusion of necessity and sufficiency. You can see that P can be false even when P→Q is true and Q is true (Table).
- Denying the antecedent—If you know that P→Q, but that P is false, and you assume that Q must therefore also be false, you are making an error called denying the antecedent (P being the antecedent). It is sometimes called the inverse error (~P→~Q is the inverse of P→Q). You can see that Q can be true even when P→Q is true, and P is false (Table).

INDUCTIVE REASONING

When we are dealing with the realm of pure thought, we often have premises that are unquestionably true. These typically involve mathematical truths and truths made necessary by the definitions of the words we use (eg, a bachelor is an unmarried male). As medical writers, however, we typically deal with premises that describe something in the physical world. Thus, we use propositions whose truth-values are less certain (eg, they contain adjectives such as "some" or adverbs such as "usually"). The arguments that we can base on those premises are less convincing. When we are using that kind of premise, the best we can do is to formulate arguments whose conclusion is unlikely to be false.

The inductive probability of an argument is the likelihood that its conclusion will be true if all of its premises are true.

- A deductive argument is one that is intended to provide a guarantee that its conclusion is true, provided that its premises are true.
  - A deductive argument whose conclusion is always true when all of its premises are true is valid (inductive probability, 100%).
  - An argument whose inductive probability is 100% and whose premises are all true is sound.
  - If there is even the slightest possibility that the conclusion can be false when all of the premises are true, the argument is invalid.
  - The conclusion of an argument can be true even if the argument is invalid and/or contains false premises.
- An inductive argument is an argument intended to convince someone that the conclusion is unlikely to be false. Thus, its inductive probability is <100%.
- Because their inductive probability is <100%, all inductive arguments are invalid. (The conclusion can be false even if all the premises are true.)
- If the inductive probability is high, the argument is considered strong.
- If the premises of a strong argument are all true, the argument is described as cogent. Its conclusion is unlikely to be false.

Many people have seen lists of logical fallacies on the Internet but don't understand how to use that information. A fallacy is an error in reasoning. A deductive argument that contains a logical fallacy is invalid, which means that the conclusion can be false even if all the premises are true. However, the presence of fallacies or false premises in an argument does not mean that the conclusion is false. (If you reject a conclusion because you spotted a fallacy in the argument, you make an error called the fallacy fallacy.) Similarly, the presence of a logical fallacy in an inductive argument does not mean that the conclusion is false. It simply means that the argument is invalid (but all inductive arguments are invalid). The real question is whether the fallacy seriously weakens the argument.

Consider the argument from authority. When you make an argument from authority, you cite expert opinion to support your argument. This argument is invalid because it is possible for the expert's opinion to be wrong. But if the expert is reliable, then it is unlikely that the expert will be

wrong. So, the expert's opinion can add to the strength of an inductive argument.

The conclusion of an inductive argument can be false even if the argument is strong and the premises are all true. That's simply the nature of induction. However, an inductive argument can be so cogent (its argument so strong and its premises so undeniable) that doubt would be unreasonable. How cogent must an inductive argument be to be convincing? The answer to that question depends on the situation. What kind of decision are you going to make on the basis of that conclusion? Is the decision reversible? What are the possible consequences of making the wrong choice? Are those consequences minor or serious? Are they reversible or irreversible? If the consequences are serious and/or irreversible, you might insist on hearing an argument with a high inductive probability.

LOGICAL AND CAUSAL RELATIONSHIPS

Writers must think carefully about what a conditional statement implies, and what it does not imply. For example, consider the following statement:

If you pick up a guinea pig by the tail, its eyes fall out.

This statement is true, but not because of anything to do with the guinea pig's eyes. The conditional statement is true only because guinea pigs never have tails. Thus, the condition described in the *if*-clause can never be met. Because P is always false, then P→Q is always true.

If a causal relationship exists, then you expect to find a high correlation between the cause and its effect. But even if you find that P and Q are perfectly correlated (P is always true when Q is true, and vice versa), it does not mean that P causes Q. Correlation does not equal causality. Q might turn out to be the cause of P. Or they could both be results of some other unknown cause. Perhaps the correlation was simply a coincidence, a fluke—something that would disappear if you took a larger sample. Nevertheless, a correlation is a reason to be suspicious. (The word *suspect* comes from the Latin for "to look at secretly.") So, if you see that something important is correlated to something else, you may want to look for an explanation. A correlation could be evidence that some cause is having an effect. On the other hand, if P and Q do not seem to be correlated with each other, then a causal relationship seems less likely.

IMPLICATIONS FOR MEDICAL WRITERS

This article has provided a basic overview of the grammar of conditionals, the role of conditionality in predicate logic, and the difference between conditionality and causality. These are vital concepts for anyone who must think critically about any topic, including medicine. An understanding of the grammar of conditionals can help medical writers achieve better clarity in their writing. An understanding of the logic of conditional statements and the difference between conditionality and causality is essential for anyone who is writing about medical research. For example, you now know why expert opinion should be taken seriously (because experts are often right) but not too seriously (because experts are sometimes wrong). You also know why the materials and methods section of a study report is so important. It describes the conditions under which the study was conducted. If those conditions had been different, the results of the study might have been different.

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