Ibn Sīnā's cyclotron

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June 2010
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Ibn Sīnā in *Qiyās* i.4, page 29 line 12, gives the following example sentence:

> *Every pair of things that rotate in a circle in opposite directions, moving permanently around a single axis for both their centres of rotation, come together and move apart.*

I call this 'Ibn Sīnā's cyclotron' because of the resemblance to Rolf Wideröe's 1943 plan for a cyclotron collider:

> *If it were possible to store the particles in rings for longer periods, and if these 'stored' particles were made to run in opposite directions, the result would be one opportunity for collision at each revolution. Because the accelerated particles would move very quickly they would make many thousand revolutions per second and one could expect to obtain a collision rate that would be sufficient for many interesting experiments. (Wideröe Autobiography ed. Waloschek)*

We will see that this comparison is not fatuous.

What point is Ibn Sīnā making with his cyclotron? The answer is not obvious. We need to look at several levels of context:

- The paragraph and section in which the cyclotron appears.
- The book *Qiyās* in which the cyclotron appears.
- Ibn Sīnā's logic as a whole.
- The general features of aristotelian logic.

The main sources for Ibn Sīnā's logic are:

- The logic part of his encyclopedic book *Šifā'*.
  This part runs to over 2000 pages.
  It contains the book *Qiyās*, about 550 pages,
  in which Ibn Sīnā discusses syllogisms,
  setting out the views in (the Arabic translation of)
  Aristotle's *Prior Analytics*,
  some of the views of commentators,
  and a defence of Ibn Sīnā's own views.
  (There is a critical edition,
  but only the propositional logic part is translated.)

- The logic part of a much shorter book *Easterners*,
  in which Ibn Sīnā gives his own views without
  comparison with those of Aristotle and earlier
  commentators,
  and generally without supporting arguments.
  (No critical edition or translation.)

Ibn Sīnā's *Išārāt*, probably a late work,
has material on logic which was very influential in the later Arabic tradition, and Western translations are available, but it is not the best exposition of Ibn Sīnā's own views.

In the *Šifā'* Ibn Sīnā demands an active reader:

- 'Check this for yourself.'
- 'Do the remaining cases.'
- 'You already know how to handle this kind of argument.'
- (Etc.)

In this spirit we will treat some of his examples as exercises for us.

Arabic translation of *Prior Analytics*	Ibn Sīnā's *Qiyās*
Generalities on deduction	1.1,2,6,7 Generalities on deduction
—	1.3,4,5 Types of sentence*
Conversion	2.1–3 Conversion
Syllogisms with absolute sentences	2.4 Syllogisms with absolute sentences
Syllogisms with modal sentences	3; 4 Syllogisms with modal sentences
...	...

*The cyclotron is in here.

The types of sentence in 1.3,4 illustrate various kinds of theoretical discourse:
mathematical (e.g. the cyclotron), physical, biological, geographical, metaphysical, theological..
Their forms are different from anything in Aristotle.

Prima facie implication: *Aristotle's logic is based on the wrong sentence forms.*

Qiyās p. 30 l. 5ff:

> The First Teacher [i.e. Aristotle] unequivocally forbids us to count such sentences as 'absolute'. His exclusion of them leads to some prevarications (*maḥālāt*); we will mention these during the course of our investigations.

A cardinal teaching of Ibn Sīnā is that we generally mean more than we say.
Besides our spoken sentence, we mean a number of added 'conditions'.

Example (not Ibn Sīnā's): if I tell you

> You can see it's cloudy.

I mean

> *The people now listening to Wilfrid Hodges* can see it's cloudy *now and in Hamburg*.

Easterners p. 48 l. 5ff:

> [Errors of reasoning can occur through failing to notice added conditions about:] the difference between part and whole, or a time or a place or an attached quality or an implied event or an act or a passion or a consideration of potency versus act, or a consideration connected with an agent or a consideration connected with a patient.

In particular, added conditions on time are endemic, because things change.

Now we examine some of Ibn Sīnā's examples in 1.3,4. They will all be of the form 'Every *B* is an *A*' (which Arabic-Aristotle counts as a single form of absolute sentence).

Qiyās p. 23 l. 4:

> Everything that breathes in breathes out.

What is understood about times here?

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Qiyās p. 22 l. 12:

> Everybody who travels from Ray to Baghdad reaches Kermanshah.

What is understood about times here?

(Note: Kermanshah is halfway along the main road from Ray in Iran to Baghdad in Iraq.
It is also the birthplace of Doris Lessing.)

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Qiyās p. 70 l. 12f:

> Everybody who writes moves his hand.

What is understood about times here?

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Jan Łukasiewicz 1939, 1951 introduced a new paradigm for studying ancient logic: *Look for formal systems*.

Two motivations are visible in his writings:

(a) By using formal systems you guarantee precision. This is essential e.g. for distinguishing those places where an ancient writer is precise from those where he is vague.

(b) Logic has an objective content (like mathematics, maybe unlike metaphysics), and we need to connect ancient writers to the objective content that they knew. The main content of logic is best explained in terms of formal systems.

Neither motivation involves a claim that an ancient writer used formal systems.

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Later philosophy-based historians of traditional logic came dangerously near claiming that ancient writers themselves used formal systems.
(For Aristotle: Corcoran, Smiley.
For Ibn Sīnā: Rescher, Street.)

After Ibn Sīnā, Arabic logicians (e.g. Qazwīnī 13th c.) did construct formal calculi for Ibn Sīnā's sentence types.
Ibn Sīnā himself never did.
He has no formal system for these sentences.

Two pressing questions:

1. Given that Ibn Sīnā regards modal logic as badly based in terms of sentence types,
why does he devote two whole chapters of *Qiyās* to it?

Not our main concern today,
though there is a lot to be said about this question.
In *Easterners* Ibn Sīnā completely ignores modal syllogisms.

2. Given the importance Ibn Sīnā attaches to his sentence types, why does he not give a calculus for them?

I think we can answer this question.
Briefly, Ibn Sīnā believes that the rules of logic are contained in the *absolute* syllogisms.
The main activity of a logician is not formal calculation but *formalisation*,
which he calls 'analysis' (*taḥlīl*) and 'verification' (*taḥqīq*).

Easterners has masses about verification.

Ibn Sīnā regards absolute (non-modal) syllogisms as

- essential knowledge for any logician;

  (Various quotes.)

- very straightforward.

  'In analysis, do not spend too much time taking into account the forms of syllogisms for that's one of the easy parts and a sound instinct rarely makes a mistake about it; you should rather practice examining in detail the matters [of syllogisms].' (*Ibn Sīnā quoted by one of his students.*)

The main task of analysis is to paraphrase inference steps into the form of syllogisms.
To do this, we paraphrase the sentences into appropriate (absolute) syllogistic sentences.

For example truth-functional present tense 'If p then q' paraphrases into 'Every present time which is a time at which p is also a time at which q'.
(This is close to Boole.)

Note: a new paraphrase may be needed for each step in a complex argument.

The sentence types discussed above can be paraphrased to 'Every A is a B' form.

'Everything that breathes in breathes out.'
$\forall x((\exists t, x \text{ breathes in at } t) \rightarrow (\exists t, x \text{ breathes out at } t))$.

'Everybody who travels from R to B reaches K.'
$\forall(x, t)((x \text{ travels from R to B for the interval } t) \rightarrow$
$(x \text{ reaches K during } t))$.

'Everybody who writes moves his hand.'
$\forall(x, t)((x \text{ writes at } t) \rightarrow (x \text{ moves his hand at } t))$.

Ibn Sīnā's reduction of modal sentences to absolute:

'Every B is an A, necessarily.'
$\forall x([\exists t, x \text{ is a } B \text{ at } t] \rightarrow [\forall t([x \text{ exists at } t] \rightarrow [x \text{ is an } A \text{ at } t])])$.

'Every B is an A, possibly.'
$\forall x([\exists t, x \text{ is a } B \text{ at } t] \rightarrow [\exists t, x \text{ is an } A \text{ at } t])$.

I believe his claim is not that 'necessarily' and 'possibly' mean this, but that for purposes of logical deduction there is no loss in supposing that they do.
Either way, this is very disruptive of Aristotle's position.

Now the cyclotron:

'Every pair of things that rotate in a circle in opposite directions, moving permanently around a single axis for both their centres of rotation, come together and move apart.'
$\forall(x, y)((x, y$ rotate permanently around each other etc.$) \rightarrow$
$(x, y$ come together, move apart, come together,
move apart etc.$))$

The problem is to formalise the predicate.
At first glance we need two quantifiers of different types:
$\forall t\ ((x, y$ come together at $t) \rightarrow$
$\exists u(t < u \wedge x, y$ move apart at $u))$
etc.

Ibn Sīnā himself comments in this paragraph:

- Not a necessity proposition,
  because the coming together is not permanent.
- In some sense a possibility proposition,
  because the coming together happens sometime.
- Nevertheless the coming together is not at a time that can be specified in terms of the subject.

His central point is still obscure, but I think it's as follows.

For Ibn Sīnā, an existential quantifier in a theory is a confession of ignorance. A favourite example of his:

> Scammony [sometimes] purges the bile.

If we knew the causal chain, we could complete this with a condition and remove the implied existential quantifier:

> Scammony, taken in quantity X by a person in condition Y, always purges the bile.

(This idea came west with Ibn Sīnā's medicine, and was ridiculed by Molière – 'virtus dormitiva'.)

I think the main point of the cyclotron is probably that without further information on times etc. we can't remove the existential quantifier in the predicate.

There is quite a lot in Ibn Sīnā about removing existential quantifiers by means of definable Skolem functions. I think it has not yet been looked at by anybody who knows the relevant logic.

Later Suhrawardi picked up this theme. Writers on Suhrawardi note it but confess they don't have the logic.

The two aristotelian logicians most closely comparable with Ibn Sīnā on analysis are Leibniz and Frege (though neither of them knew Ibn Sīnā's work).

Leibniz: More complex sentences are brought under Aristotle's rules by paraphrase or 'grammatical analysis'. These steps in reasoning are 'non-syllogistic'.

Frege: The non-logical steps are not 'objective'; they rely on 'psychological' intuition and 'changes of viewpoint'. Rebuild logic so that non-logical steps are eliminated. For example have both quantifier rules and propositional ones in a single calculus, to eliminate the switch to propositional logic mentioned above.

How to handle inner quantifiers,
when they can't be amalgamated with outer ones?

One method (cf. natural deduction) is to have rules that replace quantifiers by parameters.

Another method (implicit in some modern systems) is to use universal closures of rules of inference.

Frege is undecided about this; cf. his 'latin letters'.
There are traces of both approaches in Ibn Sīnā,
but nothing definitive.

I leave it to you to draw morals.

My own prejudice:
The key historical questions are always

(1) What question is the author trying to answer?

(2) What is the objective content of the author's answer?

The key method is always to read and read again, taking into account all levels of context.

Any modern formalism is OK for answering (2), provided that you don't ascribe to the author an approach that the author never took.

A preliminary translation of section 1.3 of *Qiyās* (the one before the cyclotron) is at `http://wilfridhodges.co.uk/arabic08.pdf`.

Tony Street, *Arabic Sciences and Philosophy* 20 (2010) 119–124, translates comments of Tūsī on the part of *Qiyās* containing the cyclotron. But I don't think Tūsī has much idea what the cyclotron is about.

John McGinnis, 'Scientific methodologies in medieval Islam', *J. History of Philosophy* 41 (2003) 307–327. (Ibn Sīnā on scammony.)

Suhrawardi, *The Philosophy of Illumination*, ed. John Walbridge and Hossein Ziai, Brigham Young University Press, Provo Utah 1999. (P. 14ff on Skolem functions.)