

Prague Treebanking for Everyone

Prague Arabic Dependency Treebank

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In PADT, which now consists of the **morphological** and the **analytical** levels of description of Arabic, the annotation of **tectogrammatics** and **information structure** is being established.

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- 2 Morphology
 - MorphoTrees
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He will notify them about that through SMS messages, the Internet, and other means. سيخبرهم بذلك عن طريق الرسائل القصيرة والإنترنت وغيرها.

String	Token	Token Tag	Buckwalter's M-Tags	Token Form	Token Gloss
	F-----	FUT		sa-	will
سيخبرهم	VIIA-3MS--	IV3MS+IV+IVSUFF_MOOD:I		yu-ḥbir-u	he-notify
	S----3MP4-	IVSUFF_DO:3MP		-hum	them
بذلك	P-----	PREP		bi-	about/by
	SD----MS--	DEM_PRON_MS		dālika	that
عن	P-----	PREP		ʿan	by/about
طريق	N-----2R	NOUN+CASE_DEF_GEN		ṭarīq-i	way-of
الرسائل	N-----2D	DET+NOUN+CASE_DEF_GEN		ar-rasāʾil-i	the-messages
القصيرة	A----FS2D	DET+ADJ+NSUFF_FEM_SG+ +CASE_DEF_GEN		al-qaṣīr-at-i	the-short
والإنترنت	C-----	CONJ		wa-	and
	Z-----2D	DET+NOUN_PROP+ +CASE_DEF_GEN		al-ʾinternet-i	the-internet
وغيرها	C-----	CONJ		wa-	and
	FN-----2R	NEG_PART+CASE_DEF_GEN		ḡayr-i	other/not-of
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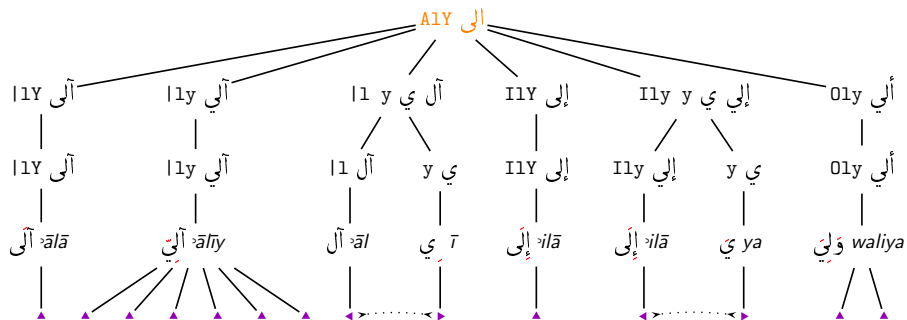
MorphoTrees

Suppose you can list **morphological analyses** for a given **input string** ...

Morphs	Form	Token Tag	Lemma	Glosses per Morph
1aY+(null)	ṡālā	VP-A-3MS--	ṡālā	promise/take an oath + he/it
liy~	ṡālīy	A-----	ṡālīy	mechanical/automatic
liy~+u	ṡālīy-u	A-----1R	ṡālīy	mechanical ... + [def.nom.]
liy~+i	ṡālīy-i	A-----2R	ṡālīy	mechanical ... + [def.gen.]
liy~+a	ṡālīy-a	A-----4R	ṡālīy	mechanical ... + [def.acc.]
liy~+N	ṡālīy-un	A-----1I	ṡālīy	mechanical ... + [indef.nom.]
liy~+K	ṡālīy-in	A-----2I	ṡālīy	mechanical ... + [indef.gen.]
l +	ṡāl	N-----R	ṡāl	family/clan +
+ iy	-ī	S-----1-S2-	ī	+ my
IilaY	ṡilā	P-----	ṡilā	to/towards
Iilay +	ṡilay	P-----	ṡilā	to/towards +
+ ya	-ya	S-----1-S2-	ya	+ me
0a+liy+(null)	ṡa-lī	VIIA-1-S--	waliya	l + follow/come after + [ind.]
0a+liy+a	ṡa-liy-a	VISA-1-S--	waliya	l + follow/come after + [sub.]

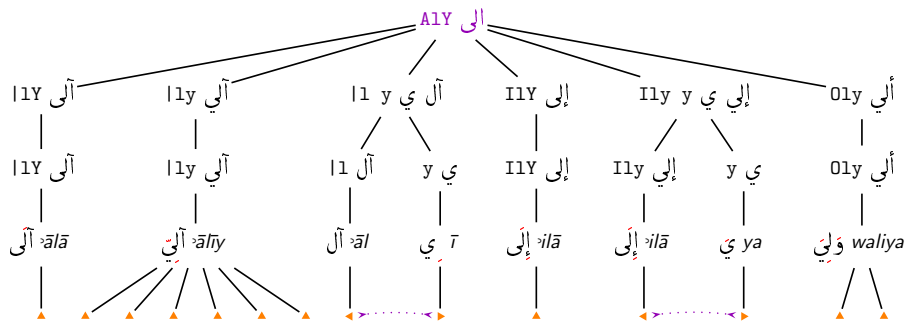
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... organize the analyses into a hierarchy with the **string** as its **root**



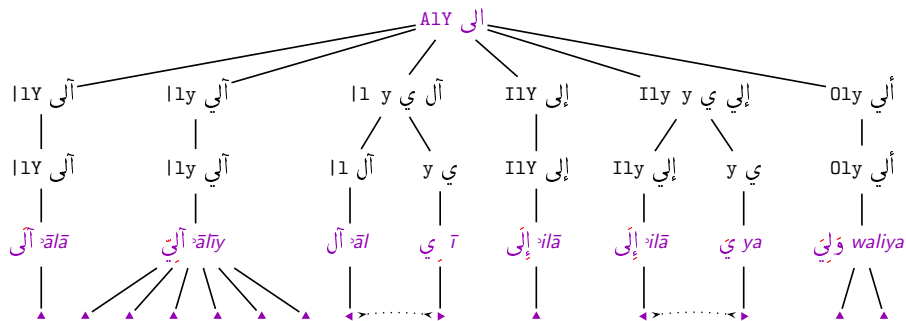
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... organize the analyses into a hierarchy with the **string** as its **root** and the **full tokens** as the **leaves**



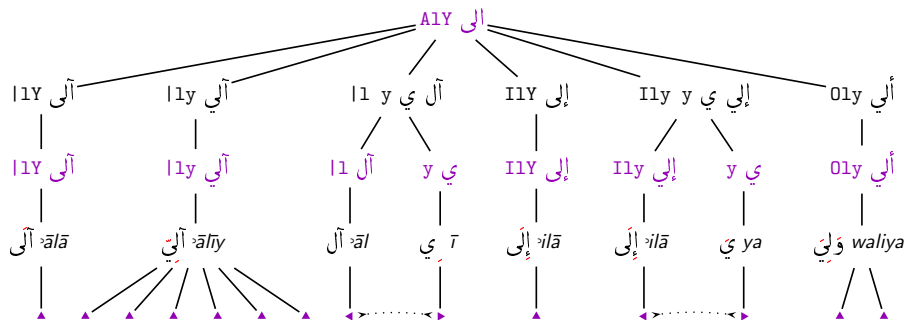
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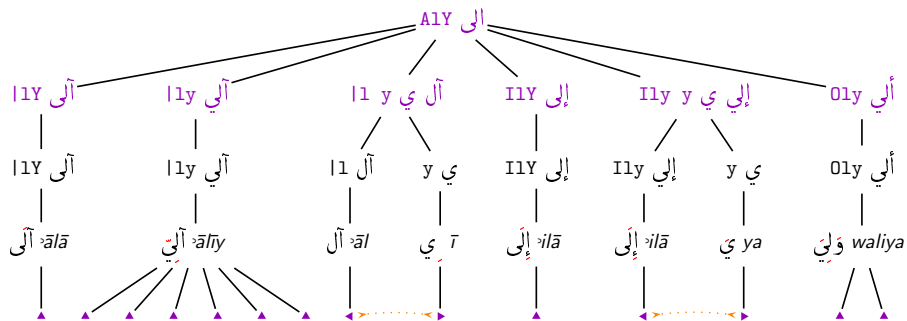
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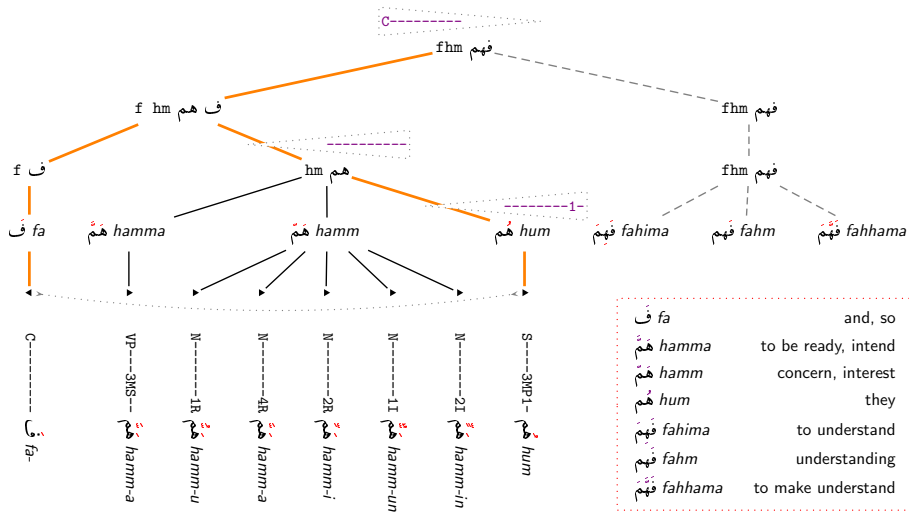


MorphoTrees

... organize the analyses into a hierarchy with the **string** as its **root** and the **full tokens** as the **leaves**, grouped by their **lemmas**, **canonical forms** and **partitionings** of the string into such forms:



MorphoTrees



ElixirFM

ElixirFM is a high-level implementation of **Functional Arabic Morphology**.

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The lexicon of ElixirFM is derived from the open-source **Buckwalter lexicon** and from the **PADT annotations**. It is **redesigned** in important respects.

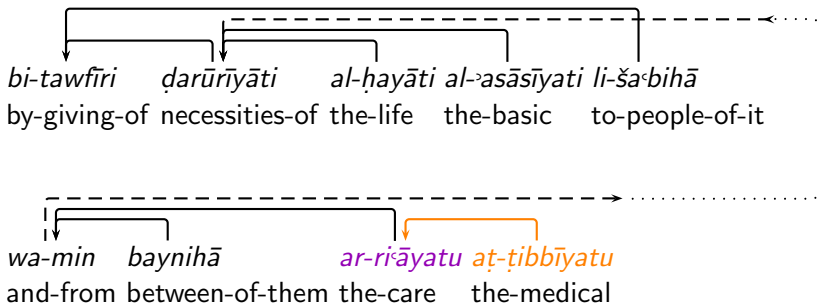
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Dependency vs. Linearity

... by providing the basic necessities of life to its people, including medical care ...

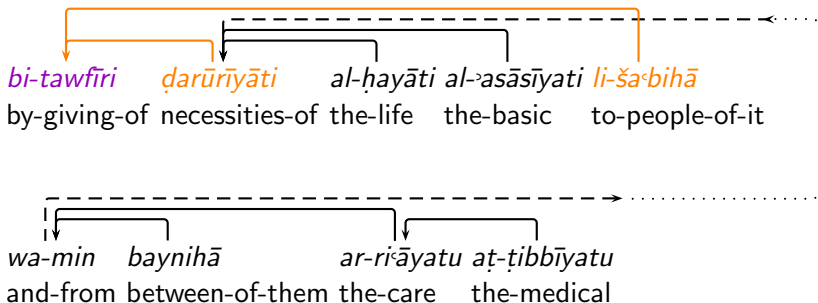
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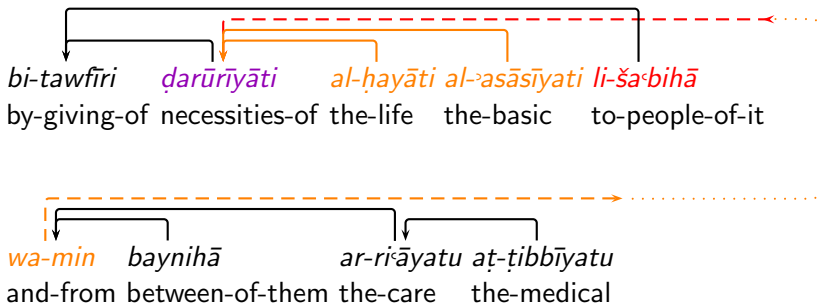
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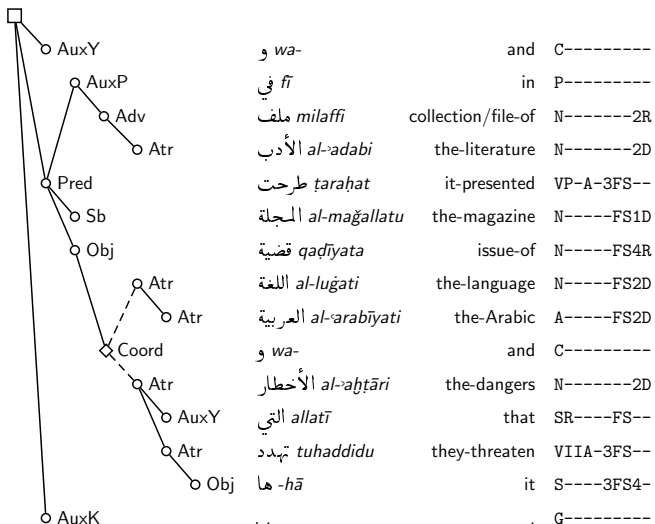


Dependency vs. Linearity

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 بتوفير ضروريات الحياة الأساسية لشعبها ومن بينها الرعاية الطبية

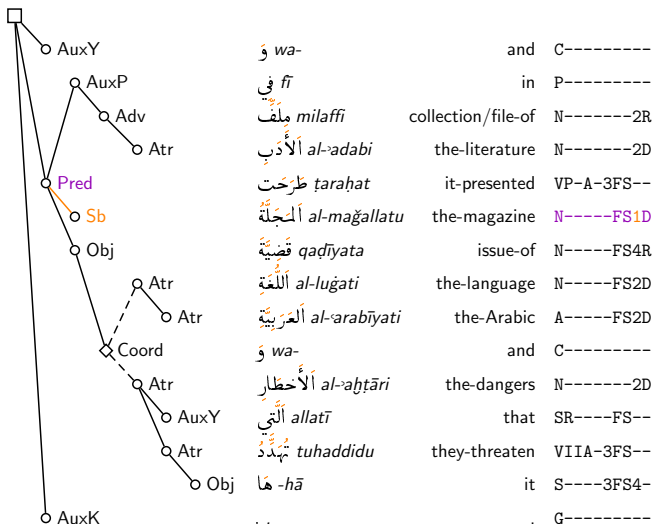


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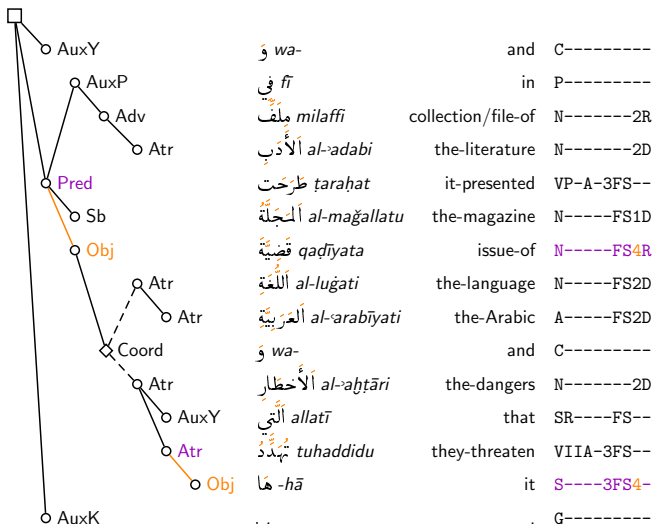
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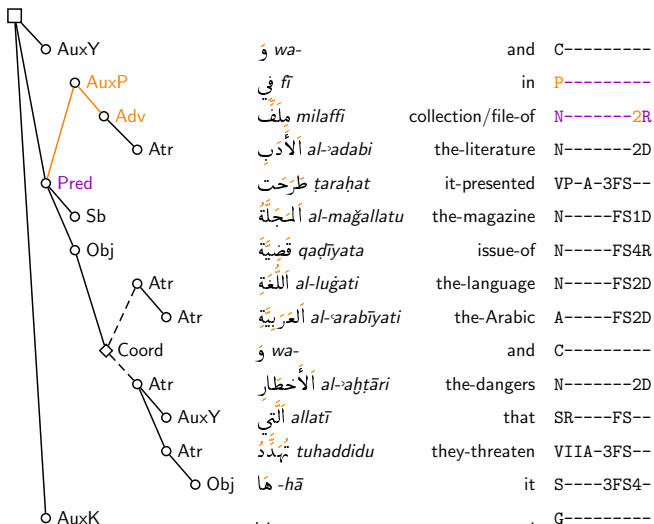
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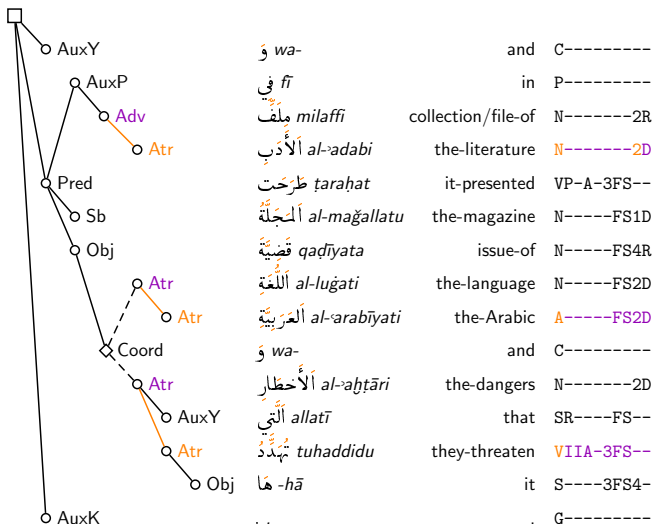


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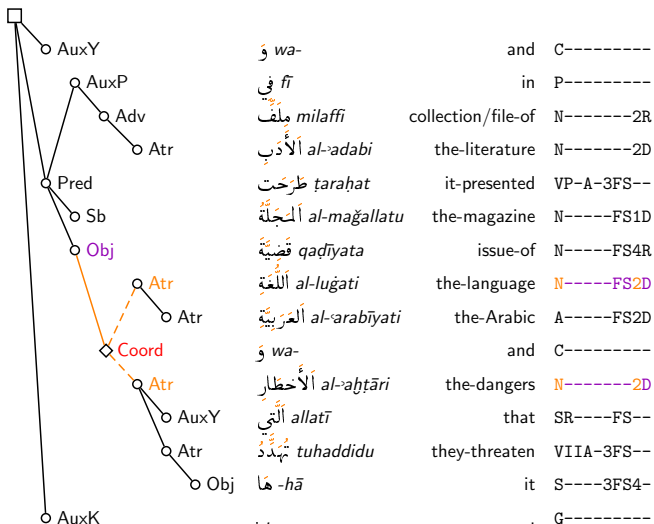
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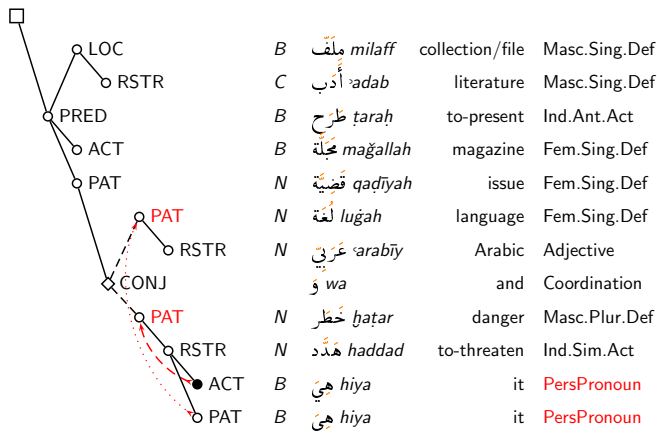


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Tectogrammatics

Description of **linguistic meaning** in its **semantic** and **pragmatic** aspects.



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Buckwalter Transliteration

يُولَدُ جَمِيعُ النَّاسِ أحرَارًا مُتَسَاوِينَ فِي الكَرَامَةِ وَالْحُقُوقِ. وَقَدْ وَهَبُوا عَقْلاً وَضَمِيرًا وَعَلَيْهِمْ
أَنْ يُعَامَلَ بَعْضُهُمْ بَعْضًا بِرُوحِ الإِخَاءِ.

yuwladu jamiyEu {ln~aAsi OaHArFA mutasaAwiyna fiy
{lokaraAmapI wa {loHuquwqi. waqado wuhibuWA EaqlAF
waDamiyrFA waEalayohimo Oano yuEaAmila baEoDuhumo baEoDFA
biruwHi {loIixaA'i.

يولد جميع الناس أحرارا متساوين في الكرامة والحقوق. وقد وهبوا عقلا وضميرا وعليهم
أن يعامل بعضهم بعضا بروح الإخاء.

ywld jmyE AlnAs OHrArA mtsAwyn fy AlkrAmp wAlHqwq. wqd
whbWA EqLA wDmyrA wElyhm On yEAml bEDhm bEDA brwH AlIxA'.

Notation of ArabT_EX

يُولَدُ جَمِيعُ النَّاسِ أَحْرَارًا مُتَسَاوِينَ فِي الْكِرَامَةِ وَالْحُقُوقِ. وَقَدْ وَهَبُوا عَقْلًا وَضَمِيرًا وَعَلَيْهِمْ أَنْ يُعَامَلَ بَعْضُهُمْ بَعْضًا بِرُوحِ الْإِخَاءِ.

يولد جميع الناس أحرارا متساوين في الكرامة والحقوق. وقد وهبوا عقلا وضميرا وعليهم أن يعامل بعضهم بعضا بروح الإخاء.

Yūladu ġamī'u 'n-nāsi 'aħrāran mutasāwīna fī 'l-karāmati wa-'l-ħuqūqi. Wa-qad wuhibū 'aqlan wa-ḍamīran wa-ʿalayhim 'an yuʿāmila baḍhum baḍan bi-rūḥi 'l-iḥā'i.

```
\cap yUladu ^gamI'u an-nAsi 'a.hrAraN mutasAwIna fI
al-karAmATi wa-al-.huqUqi.
```

```
\cap wa-qad wuhibUA 'aqlaN wa-.damIraN wa-'alayhim 'an
yu'Amila ba'.duhum ba'.daN bi-rU.hi al-'i_hA'i.
```

Encode Arabic

biruwHi {loIixaA'i ← بِرُوحِ الْإِخَاءِ ← bi-rU.hi al-'i_hA'i

Implemented in **Perl** and available on CPAN as **Encode-Arabic**:

```
$encoded = encode "buckwalter", decode "arabtex", $decoded
$encoded = encode("buckwalter", decode("arabtex", $decoded))
```

Implemented in **Haskell** and available along with **ElixirFM**:

```
encoded = encode Buckwalter $ decode ArabTeX decoded
encoded = encode Buckwalter (decode ArabTeX decoded)
encoded = (encode Buckwalter . decode ArabTeX) decoded
```

```
[cmd] decode ArabTeX < decode.d | encode Buckwalter > encode.d
```

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encoded = encode Buckwalter $ decode ArabTeX decoded
encoded = encode Buckwalter (decode ArabTeX decoded)
encoded = (encode Buckwalter . decode ArabTeX) decoded
```

```
[cmd] decode ArabTeX < decode.d | encode Buckwalter > encode.d
```

Encode Arabic

biruwHi {loIixaA'i ←  ← bi-rU.hi al-'i_hA'i

Implemented in **Perl** and available on CPAN as **Encode-Arabic**:

```
$encoded = encode "buckwalter", decode "arabtex", $decoded
$encoded = encode("buckwalter", decode("arabtex", $decoded))
```

Implemented in **Haskell** and available along with **ElixirFM**:

```
encoded = encode Buckwalter $ decode ArabTeX decoded
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- Buckwalter, Tim. [Buckwalter Arabic Morphological Analyzer 1.0](#). LDC catalog number LDC2002L49, ISBN 1-58563-257-0. 2002
- Forsberg, Markus and Aarne Ranta. [Functional Morphology](#). Proceedings of ICFP 2004, pages 213–223. ACM Press. 2004
- Lagally, Klaus. [ArabTeX: Typesetting Arabic and Hebrew, User Manual Version 4.00](#). Technical Report 2004/03, Fakultät Informatik, Universität Stuttgart. 2004
- Sgall, Petr and Eva Hajičová and Jarmila Panevová. [The Meaning of the Sentence in Its Semantic and Pragmatic Aspects](#). Academia, Prague. 1986
- Smrž, Otakar and Petr Pajas. [MorphoTrees of Arabic and Their Annotation in the TrEd Environment](#). Proceedings of the NEMLAR Conference 2004, pages 38–41. 2004

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