Linguistic insights from computational modeling of *Plains Cree* morphology

Antti Arppe, Lene Antonsen, Trond Trosterud, Conor Snoek, Dorothy Thunder, Atticus Harrigan, Jordan Lachler, Jean Okimâsis & Arock Wolvengrey
21st Century Tools for Indigenous Languages

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• Community contacts
  – Miyo Wahkohtowin Education Board, Maskwacis, AB
  – Etc.
Many shoulders to stand upon

- Cree elders, instructors, language activists, and speakers
- Alberta Elders’ Cree Dictionary
  - Earle Waugh et al.
- Maskwacis Cree dictionary
  - Miyo Wahkohtowin Education
- Cree words
  - Arok Wolvengrey
- Cree grammatical descriptions
  - Jean Okimâsis, H. Christoph Wolfart
- Cree text collections
  - H. Christoph Wolfart, Kevin Russell
  - Patricia Demers, Naomi L. McIlwraith, Dorothy Thunder
  - Bloomfield
  - Hopefully many more ...
21st century tools for indigenous languages: 2013-2016

Using Plains Cree as the spearhead language, this project will produce tools such as spell-checkers, language teaching and learning software, and text-to-speech synthesizers.

These technologies are available for world’s majority languages (e.g. English), but have so been created for only a few minority languages. In providing minority language speakers with these applications the project aims to facilitate the use of minority languages in all spheres of life by community members.
21CTfIL – Tangible deliverables

• Toolkit
  – Intelligent web-based dictionaries
    • Facilitate language comprehension by native speakers and language learners → ease-of-use
  – spell-checker
    • creation of good-quality texts in that language by its own speakers
  – Intelligent language training and education applications
    • revitalization of knowledge about the language’s structure
  – basic text-to-speech synthesizer
    • enabling the visually impaired to access and hear information in their native language
  – linguistic analysis tools
    • research use
Our dog slept by the door.
Our dog slept by the door.
nitêminan nipâw sisone iskwâhtemihk

sigma sigma rho rho Delta beta nu nu
nitêminan nipâw sisone iskwâhtemihk
nitêminan nipâw sísone iskwâhtemihk
itwêwasinahikana

nêhiyawêwin → âkayâsimowin

NAWASÔNA TÂNISI KÂ-ISI-NEHIYAWASINAHIKÉYAN

papêyâhtak nêhiyawasinahikêwin (aâ)
wêhci-masinahikêwin (a → a ~ â)

nitona nêhiyaw-itwêwin ta-miskaman âkayâsiwascikêwin (êkwa mîna tânisi kâ-isî-âniskôpitamihk).

kotaka itwêwasinahikana
itwēwasinahikana

dog; horse; beast of burden

atim (n)

Noun Animate Singular
Possessive: 1st person exclusive plural
Dog Biscuits – Salamô âcimow

âcimow

âcimow (v) — s/he tells, s/he tells a story; s/he tells news, s/he gives an account, s/he narrates; s/he tells his/her own story

When I was a child I went to school away from my reserve. It was at Prince Albert where I went to school, there was a Residential School there where I went. There was a lot of ill treatment, but I’m not going to talk about that, I’m going to tell a story about my fellow pitiful ones, my fellow students.
Dog Biscuits – Salamô âcîmow

ispîhk

ispîhk (pcle) — when

When I was a child I went to school away from my reserve. It was at Prince Albert where I went to school, there was a Residential School there where I went. There was a lot of ill treatment, but I’m not going to talk about that, I’m going to tell a story about my fellow pitiful ones, my fellow students.
Dog Biscuits – Salamô âcimow


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Dog Biscuits – Salad


kistapînîhâhôk (n) — Prince Albert, SK; literally: place of wealth; meeting place; gathering place

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itwēwasinahikana

nēhiyawēwin → âkayâsimowin

nēhiyawēwin

nâniitawi-kiskinwahamâkosin  nitona  nitona masinahikêwinihk

NAWASÔNA TÂNISI KÂ-ISI-NÉHIYAWASINAHIKÊYAN

papéyâhtak nêhiyawasinhikêwin (ââ)

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kotaka itwēwasinahikana
itwēwasinahikana

nēhiyawēwin → âkayâsîmowin

NAWASÔNA TÂNISI KÂ-ISINÊHÍYAWASINAHIKÉYAN

papêyâhtak nēhiyawasinahikêwin (aâ)
wêhci-masinahikêwin (a → a ~ â)

kiskinwahamâkosiw (v)
- s/he learns; s/he is a student, s/he attends school; s/he is taught

nēhiyawēwin : itwēwina / Cree : Words

kotaka itwēwasinahikana
Finite state transducers – components
(Beesley & Karttunen, 2003)

*nicasocinisinâna*  

**“surface” form**

1. Affixation sequence rules (associated with morphological features) → LEXC

2. Morphophonological rules → TWOLC

3. Affix agreement rules “filters” → LEXC

**“deep/underlying” form**

\[ \text{astotin+N+IN+Dim+Pl+Px1Pl} \]
Modeling affix and stem variation

• In computational modeling, we are trying to model the entire lexicon.
• Level of detail and explicitness required for a computational model beyond many grammatical descriptions:
  – Individual morphological phenomenon types (possession, locative, plural, obviation) are typically individually explained, but not all their possible combinations are necessarily covered.
• Identifying the exhaustive set of all paradigm types covering the entire lexicon is indispensable:
  – Specification of the full set of possible affix (sequence) realizations and the associated morphological features for each paradigm/stem type.
  – Classification of stems per each word class according to paradigm types.
  – But are these abstractions/generalizations “creating” some individual forms which do not in practice exist in the linguistic system? ← rare or pragmatically odd forms.
The necessity of fieldwork?

• “missing” theoretically possible morphological forms need to be submitted to fluent native speaker scrutiny
  – But considerable variety among native speaker specialists regarding the acceptability of some non-core inflected forms
  – Individual speakers have only partial experience of the full possible extent of a language
Plains Cree – nominal morphotax

- stem+NUM
- stem+OBV
- stem+LOC

- stem+DIM+NUM
- stem+DIM+OBV
- stem+DIM+LOC

- POSS+stem+POSS+NUM
- POSS+stem+DIM+POSS+NUM
- POSS+stem+DIM+POSS+OBV
- POSS+stem+POSS+LOC
- POSS+stem+DIM+POSS+LOC
Nominal inanimate morphotax

POSS
ni: Px1Sg
ki: Px2Sg
o: Px3Sg
ni: Px1Pl
ki: Px12Pl
ki: Px2Pl
o: Px3Pl
o: Px4

NI-stem: N+AN
NI-w-stem: N+AN

DIM
is: Dim

DIM
is: Dim

LOC
ihk: Loc

NUM
Ø: Sg
ak: Pl

Ø

Ø

Ø
General morphotactic map → paradigms and variation
Plains Cree nominal paradigm types (Wolvengrey, p.c. 2014)

• Inanimate: 10
  – NI1 C-Initial Regular NI Stem: cîmân “canoe, boat”
  – NI1 V-Initial Regular NI Stem: astotin “hat, cap”
  – NI2 C-Initial VW NI Stem: mîkisasâkay “beaded coat, beaded dress”
  – NI2 V-Initial VW NI Stem: oskasâkay “new coat, new dress”
  – NI3 C-Initial Cw NI Stem: pahkêkin:pahkêkinw- “leather, rawhide”
  – NI3 V-Initial Cw NI Stem: askêkin:askêkinw- “fresh rawhide”
  – NI4 C-Initial Single-Syllable NI Stem: wâw– “egg”
  – NI4 V-Initial Single-Syllable irregular NI Stem: ôsi:ôs- “canoe, boat”
  – NI4w C-Initial Single-Syllable-/w/ NI Stem: mihkw– “blood”
## Nominal inanimate paradigms – affix/feature bundles

### NI<sub>1</sub>
**Consonant-Initial Regular NI Stem**

example: *cimăn* – “canoe, boat”

<table>
<thead>
<tr>
<th>Prefix</th>
<th>NI&lt;sub&gt;1&lt;/sub&gt; Stem</th>
<th>Ending</th>
<th>Word</th>
<th>Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>singular</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1s</td>
<td>ni–</td>
<td>(-im)</td>
<td>cimăn</td>
<td>canoe</td>
</tr>
<tr>
<td>2s</td>
<td>ki–</td>
<td>(-im)</td>
<td>icimăn</td>
<td>my canoe</td>
</tr>
<tr>
<td>1p</td>
<td>ni–</td>
<td>(-im)</td>
<td>inan</td>
<td>your canoe</td>
</tr>
<tr>
<td>21</td>
<td>ki–</td>
<td>(-im)</td>
<td>ikimănawnaw</td>
<td>our canoe</td>
</tr>
<tr>
<td>2p</td>
<td>ki–</td>
<td>(-im)</td>
<td>ikimănaw</td>
<td>your canoe</td>
</tr>
<tr>
<td>3s</td>
<td>o–</td>
<td>(-im)</td>
<td>ocimăn</td>
<td>his/her canoe</td>
</tr>
<tr>
<td>3p</td>
<td>o–</td>
<td>(-im)</td>
<td>ocimănaw</td>
<td>their canoe</td>
</tr>
<tr>
<td>4</td>
<td>o–</td>
<td>(-im)</td>
<td>oicimănaw</td>
<td>another’s canoe</td>
</tr>
<tr>
<td><strong>plural</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1s</td>
<td>ni–</td>
<td>(-im)</td>
<td>cimăn</td>
<td>canoes</td>
</tr>
<tr>
<td>2s</td>
<td>ki–</td>
<td>(-im)</td>
<td>icimăn</td>
<td>your canoes</td>
</tr>
<tr>
<td>1p</td>
<td>ni–</td>
<td>(-im)</td>
<td>inana</td>
<td>your canoes</td>
</tr>
<tr>
<td>21</td>
<td>ki–</td>
<td>(-im)</td>
<td>ikimänaw</td>
<td>our canoes</td>
</tr>
<tr>
<td>2p</td>
<td>ki–</td>
<td>(-im)</td>
<td>ikimänawa</td>
<td>your canoes</td>
</tr>
<tr>
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<td>(-im)</td>
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<td>his/her canoes</td>
</tr>
<tr>
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<td>o–</td>
<td>(-im)</td>
<td>ocimänawa</td>
<td>their canoes</td>
</tr>
<tr>
<td>4</td>
<td>o–</td>
<td>(-im)</td>
<td>oicimänawa</td>
<td>another’s canoes</td>
</tr>
<tr>
<td><strong>locative</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1s</td>
<td>ni–</td>
<td>(-im)</td>
<td>cimânihk</td>
<td>in the canoe(s)</td>
</tr>
<tr>
<td>2s</td>
<td>ki–</td>
<td>(-im)</td>
<td>ikimânihk</td>
<td>in your canoe(s)</td>
</tr>
<tr>
<td>1p</td>
<td>ni–</td>
<td>(-im)</td>
<td>inâhk</td>
<td>your canoe(s)</td>
</tr>
<tr>
<td>21</td>
<td>ki–</td>
<td>(-im)</td>
<td>ikimânâh</td>
<td>in our canoe(s)</td>
</tr>
<tr>
<td>2p</td>
<td>ki–</td>
<td>(-im)</td>
<td>ikimânâhk</td>
<td>in your canoe(s)</td>
</tr>
<tr>
<td>3s</td>
<td>o–</td>
<td>(-im)</td>
<td>ocimân</td>
<td>in his/her canoe(s)</td>
</tr>
<tr>
<td>3p</td>
<td>o–</td>
<td>(-im)</td>
<td>ocimânâh</td>
<td>in their canoe(s)</td>
</tr>
<tr>
<td>4</td>
<td>o–</td>
<td>(-im)</td>
<td>ocimâniyihk</td>
<td>in another’s canoe(s)</td>
</tr>
<tr>
<td><strong>dim</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>–is(is)</td>
<td>cimânis</td>
<td>small canoe</td>
</tr>
</tbody>
</table>

*The Diminutive derivation will also convert any /t/ present in the stem (and usually the prefix as well) to [c] (i.e. /t/ > [c]).

All derived diminutive verbs become regular stems of the appropriate animacy.
Plains Cree nominal paradigms types (Wolvengrey, p.c. 2014)

• Animate: 10
  – NA1 C-Initial Regular NA Stem : pahkwêsikan “bannock”
  – NA1 V-Initial Regular NA Stem : asikan “sock”
  – NA2 C-Initial V-Glide NA Stem : kihc-ôkiniy “tomato”
  – NA2 V-Initial V-Glide NA Stem : ayapiy “net”
  – NA3 C-Initial C-/w/ NA Stem : masinahikanâhtik:masinahikanâhtikw— “pencil”
  – NA3 V-Initial C-/w/ NA Stem : askihk:askihkw— “kettle, pail”
  – NA4 C-Initial Single-Syllable NA Stem : niska:nisk- “goose” (and siht— “spruce”)
  – NA4 V-Initial Single-Syllable NA Stem : êsa:ês- “clam; shell”
  – NA4w C-Initial Single-Syllable-/w/ NA Stem : wâhkwa:wâhkw- “roe, fish eggs; lump of roe”
  – NA4w V-Initial Single-Syllable-/w/ NA Stem : ihkwa:ihkw- “louse”
## Nominal Paradigms - Animé

<table>
<thead>
<tr>
<th>Dim</th>
<th>locative</th>
<th>obviative</th>
<th>plural</th>
<th>singular</th>
</tr>
</thead>
<tbody>
<tr>
<td>4p</td>
<td>-iwha</td>
<td>-iwha</td>
<td>-iwha</td>
<td>-iwha</td>
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<tr>
<td>3p</td>
<td>-ihk</td>
<td>-iwha</td>
<td>-iwha</td>
<td>-iwha</td>
</tr>
<tr>
<td>3s</td>
<td>-ihk</td>
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<tr>
<td>2p</td>
<td>-ihk</td>
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<tr>
<td>2s</td>
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<td>-ihk</td>
<td>-ihk</td>
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<tr>
<td>1p</td>
<td>-ihk</td>
<td>-ihk</td>
<td>-ihk</td>
<td>-ihk</td>
</tr>
<tr>
<td>1s</td>
<td>-ihk</td>
<td>-ihk</td>
<td>-ihk</td>
<td>-ihk</td>
</tr>
</tbody>
</table>

### Example: **pahkw**

<table>
<thead>
<tr>
<th>Dim</th>
<th>in another hammock(s)</th>
<th>in your hammock(s)</th>
<th>in our hammock(s)</th>
<th>in your hammock(s)</th>
<th>in your hammock(s)</th>
<th>in my hammock(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4p</td>
<td>-iwha</td>
<td>-iwha</td>
<td>-iwha</td>
<td>-iwha</td>
<td>-iwha</td>
<td>-iwha</td>
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<tr>
<td>3p</td>
<td>-ihk</td>
<td>-ihk</td>
<td>-ihk</td>
<td>-ihk</td>
<td>-ihk</td>
<td>-ihk</td>
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<tr>
<td>3s</td>
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<td>-ihk</td>
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<tr>
<td>2p</td>
<td>-ihk</td>
<td>-ihk</td>
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<td>-ihk</td>
<td>-ihk</td>
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<td>1p</td>
<td>-ihk</td>
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<tr>
<td>1s</td>
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<td>-ihk</td>
<td>-ihk</td>
<td>-ihk</td>
<td>-ihk</td>
<td>-ihk</td>
</tr>
</tbody>
</table>

### Translation

- **pahkw**: Small piece of bannock in another's hammock(s)
- **ik**: In your hammock(s)
- **kh**: In our hammock(s)
- **a**: Your hammock
- **k**: My hammock

### Diminutive Derivation

- NA Stem + /-t/ > [c]
Nouns classified according to paradigm types in *Cree: Words* (Wolvengrey 2001)

NI-1 acâwêwikamikos little store, shop
NI-1 acikâsimin evergreen berry; kinnikinnick berry, ground cedar berry
NI-3 acikâsipakwa: acikâsipakw- bearberry leaves; plant-like evergreen (mixed with tobacco); Arctostaphylos uva-ursi
NI-1 acimomêyisimin cactus berry, red berry from a cactus; literally: "little dog-feces berry"
NI-1 ahcahkowin spirituality
NI-2 ahcâpahciy bowstring
NI-3 ahcâpâhtik: ahcâpâhtikw- bow stick, stick previously used as a bow
NI-2 ahcâpiy bow
NI-2 ahkâmasiniy round stone for breaking bones

NA-1 acâhkos star
NA-1 acihkos caribou calf, fawn
NA-1 acihkosis caribou calf, fawn
NA-1 acimosis pup, puppy; small dog
NA-1 acos arrow, little arrow
NA-1 acosis arrow, little arrow
NA-3 ahcahk: ahcahkw- soul, spirit
NA-1 ahpihc tobacco
NA-1 ahpihcis pouch, tobacco pouch
NA-1 ahpiht pouch, tobacco pouch
NA-2 ahtay pelt; fur, animal skin
NA-2 akahkway bloodsucker
NA-1 akahkwayimin spiral shell
NA-3 akask: akaskw- knobbed arrow, knob-shaped arrowhead
Plains Cree nominal paradigms types
(Wolvengrey → FST)

• Both the animate and inanimate types can be reduced to a smaller set (LEXC), using some 20 morphophonological rules (TWOLC)
  – “regular” stem variation (joiner -t- before initial Vowel vs. Consonant)
  – Stem variation involving final –w based on Wolvengrey dictionary lemma/stem data
  – Diminutive: /t/ → /c/
  – regular changes a morpheme junctions
  – etc.
“New” possible variation and subparadigms

• Determinants of -im- affix in possessive forms
• Determinants of short vs. long diminutive affix –is vs. –isis
• animate nouns and the locative form
  – e.g. atimohk
• animate nouns and the distributive form
  – groups of people and buffalos but not any other animals (bears, beavers, geese, etc.) or plants (trees)?
• mass nouns → only singular
Plains Cree noun model – post-stem animate suffix combinations

- Possessive: Ø, Diminutive: -is
- Possessive: Ø, Diminutive: -isis
- **Possessive: Ø, Diminutive: -isis & –is**
- Possessive: -im-, Diminutive: -is
- Possessive: -im-, Diminutive: -isis
- Possessive: -im-, Diminutive: -is & -isis
- Stem: -w, Possessive: -im-, Diminutive: -is

- Kinship terms: generic form (**someone’s X**)
- Kinship terms: no attested generic form (**Sg1 possessor**)
- ôho: absolute declension, Possession: none, Diminutive: none
- Number: **only singular** (only one wife/husband)

- **atim** and **mistatim**: Diminutive, Possessive
Plains Cree noun model – post-stem inanimate suffix combinations

- Stem: Ø, Possessive: Ø, Diminutive: -is
- Stem: Ø, Possessive: Ø, Diminutive: -isis
- **Stem: Ø, Possessive: Ø, Diminutive: -is- & -isis-**
- Stem: Ø, Possessive: -im-, Diminutive: -is
- Stem: Ø, Possessive: -im-, Diminutive: -isis
- Stem: Ø, Possessive: -im-, Diminutive: -is & -isis

- Stem: -w, Possessive: -im-, Diminutive: -is, only Sg (1-syllable)
- ôsi (irregular)
- Stem: Inalienable, Number: Only Sg
Less clear cases

- Possibly determined by semantic groupings not explicitly specified in lexical resources
- Possibly even determined at the lemma level
- Or possibly an indication of general or areal/dialectal variation

- Resolution?
  - Specification through corpora
  - Specification through native speaker judgments
  - Allowing for variation?
Locatives and grammatical vs. semantic animacy

- Types
  - inanimate: 184 vs. animate: 22
- Tokens
  - inanimate: 1381 vs. animate: 180
- Animate + Locative
  - 40 ayihk aya+N+AN+Loc ‘one, person’, aya+N+IN+Loc ‘one, thing’, ayihk+Pcle ‘ah’
  - 24 minahikohk minahik+N+AN+Loc ‘pine’
  - 23 kistikänihk kistikän+N+AN+Loc ‘garden, seed’
  - 18 mîtosihk mîtos+N+AN+Loc ‘tree’
  - 9 ëyikohk ëyik+N+AN+Loc ‘ant’, ëyikohk ‘when’
  - 9 mistikohk mistik+N+AN+Loc ‘tree, stick’
  - 8 ospwâkanihk ospwâkan+N+AN+Loc ‘pipe’
  - 5 kônihk kôna+N+AN+Loc ‘snow’
  - 5 kotawânihk kotawân+N+AN+Loc ‘camp-fire’
  - 4 kihci-kîsîkhohk kihci-kîsikow+N+AN+Loc ‘angel’, kihci-kîsîk+N+IN+Loc ‘heaven’
  - 3 wîhkihkasîkanihk wîhkihkasikan+N+AN+Loc ‘cake’
  - 3 pôsiwinihk pôsiwin+N+AN+Loc ‘train’
  - 3 pahkwêsîkanihk pahkwêsi+N+AN+Loc ‘bannock, bread, flour’
  - 3 otâpânâskohk otâpânâsk+N+AN+Loc ‘wagon’
  - 3 ocâpânâskosihk otâpânâsk+N+AN+Der/Dim+N+AN+Loc ‘buggy’
  - 3 ocâpânâskosihk ocâpânâskos+N+AN+Loc ‘buggy’
  - 3 mistaskihkahk mistaskih+k+N+AN+Loc ‘kettle’
  - 3 maskimocisihk maskimocis+N+AN+Loc ‘bag’ vs. ‘bean’
  - 3 awasowi-kotawânâpiskohk awasowi-kotawânâpisk+N+AN+Loc ‘stove’
  - 3 askihkahkahk askihkah+N+AN+Loc ‘little pail’
  - 3 askihkahkahk askihkah+N+AN+Der/Dim+N+AN+Loc ‘little pail’
  - 2 îwahikanihk îwahikan+N+AN+Loc ‘pounded meat’
Distributives and animate nouns

• people/communities
• animals (anthropomorphemic uses?)
  – mostosonâhk ‘among the buffaloes’
  – maskonâhk ‘among the bears’
  – amiskonâhk ‘among the beavers’
  – sîsîpinâhk ‘among the geese’
  – kinosênâhk ‘among the fish’
• plants/trees
  – mistikonâhk ‘among the trees’
Mass nouns (only singular?)

- anômin "oatmeal; rice"
- astinwân "sinew"
- âmôsîsipâskwat "honey; literally: "bee (maple) sugar""
- kinikinik "shrub mixture (red willow bark and green leaves) used as traditional tobacco for the pipe"
- kohkôsiwiyin "bacon"
- kôna "snow"
- mihko "blood"
- pihko "soot, ashes, wood ashes, dust"
- wîko "kidney fat"
- wîni "bone-marrow; his/her bone-marrow"
- wîsakat "pepper"
- wîsi "belly-fat"

- Others? Might plural forms be possible sometimes?
Lessons learnt

• Fieldwork as a part of computational modeling is extremely time-consuming
• Grasping the full morphotax encompassing all morphological phenomena is the necessary starting point for computational modeling
• Well-structured lexicographical resources – full paradigms and accordingly classified words – are indispensable
  – Fieldwork resulting in such resources should be encouraged
  – N.B. caveats of the practical reality of full paradigms
• Modeling “regular” structural paradigm variation exposes semantic/lexical paradigm variation → evidence of areal/dialectal variation
Thank you! hay-hay! Kiitos!

kakwêcihkêmowina?