

University of South Wales Prifysgol De Cymru

# Reflections on the semantic integration of archaeological datasets and grey literature reports

Douglas Tudhope & Ceri Binding Hypermedia Research Group, University of South Wales

douglas.tudhope@southwales.ac.uk ceri.binding@southwales.ac.uk

FAIR Heritage Digital Methods, Scholarly Editing and Tools for Cultural and Natural Heritage







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## Case study of detailed research data integration

- Extracts of 5 archaeological datasets, output from NLP on extracts from 25 grey literature reports
- broad theme of wooden material, objects and samples dated via dendrochronological analysis
- Multilingual English, Dutch and Swedish data/reports
- Data integration via CIDOC CRM and Getty AAT
- 1.09 million RDF triples
- 23,594 records
- 37,935 objects
- Demonstration query builder for easier cross-search and browse of integrated datasets
- Concept based query expansion via AAT

## General workflow and architecture



## STELETO data conversion application

- A simpler, cross-platform version of the (previous project) STELLAR.Console application
- Performs bulk transformation of tabular delimited data via user-defined templates
- Cross platform (tested on Linux and Windows)
- Open source (https://github.com/cbinding/steleto)
- Flexible (can produce any textual output format)
- Simple, fast

## **ARIADNE** vocabulary mapping to Getty AAT

- Subject metadata in different languages , so potentially:
  - useful resources missed
  - false results from homographs (eg 'coin' French for corner, 'boot' German for boat and 'monster' Dutch for sample)
- Scalable solution employ hub architecture
- Getty AAT adopted (available as LOD)
- Interactive (intellectual) mapping tools developed
  - generates SKOS mapping relationships in JSON and other formats
- Mapping guidelines produced
- 6416 concepts (27 vocabularies, 12 partners) mapped

## Multilingual enrichment via AAT

- ARIADNE Registry subject enrichment service derived AAT concepts that augment subject metadata for partner resources
- When applied to ARIADNE portal this allowed the concept-based search functionality to retrieve records with metadata expressed in different languages via the AAT concepts - the AAT acting as a mapping spine
- When applied to the data integration case studies, we explored the possibility of integrating research data and archaeological grey literature in different languages via the core ontology and value vocabularies

## **NLP** methods

- Rule based Named Entity Recognition (NER) pipelines for English, Dutch, and Swedish text using GATE platform
- Builds on previous English language NLP work on archaeological grey literature
- Supported by a controlled vocabulary based on Getty AAT with mappings to Dutch and Swedish vocabulary
- Intermediate XML output with inline mark-up transformed to same RDF format as for datasets
- Different strategies explored for identifying potentially relevant material (manual, automatic)

## Illustrative examples of NLP output

Examples illustrating English, Dutch and Swedish NLP output (before transformation to RDF), with colour coding objects, materials, dates, samples):

*Two timbers dated from the west wing roof produce felling dates in the winter of AD 1735/6 and the spring of AD 1736.* 

Dendrochronologisch onderzoek door Stichting RING in Amersfoort wijst uit dat de eik waaruit de paal is vervaardigd, is geveld tussen 55 en 69 na Chr.

<mark>Prov</mark> 1 som var bearbetat <mark>virke</mark> av <mark>ek</mark> daterades till fällningsår <mark>vinterhalvåren 1536/37.</mark>

## Direct queries on RDF triple store

```
PREFIX gvp: <http://vocab.getty.edu/ontology#>
PREFIX crm: <http://www.cidoc-crm.org/cidoc-crm/>
PREFIX xl: <http://www.w3.org/2008/05/skos-xl#>
SELECT ?material COUNT(*) AS ?counter WHERE {
    ?object crm:P45_consists_of
    [gvp:prefLabelGVP [xl:literalForm ?material]] .
    }
GROUP BY ?material
ORDER BY DESC(?counter)
LIMIT 10
```

#### **SPARQL - top 10 object materials**

material	counter
"Quercus (genus)"@en	8390
"undetermined (information indicator)"@en	333
"wood (plant material)"@en	324
"Pinus sylvestris (species)"@en	311
"timbers (wood by form)"@en	310
"timber (lumber)"@en	310
"Fagus sylvatica (species)"@en	302
"Fraxinus excelsior (species)"@en	151
"Abies alba (species)"@en	109
"Ulmus (genus)"@en	99

```
PREFIX gvp: <http://vocab.getty.edu/ontology#>
PREFIX crm: <http://www.cidoc-crm.org/cidoc-crm/>
PREFIX xl: <http://www.w3.org/2008/05/skos-xl#>

SELECT ?type COUNT(*) AS ?counter WHERE {
    ?object crm:P2_has_type
    [gvp:prefLabelGVP [xl:literalForm ?type]] .
    }
GROUP BY ?type
ORDER BY DESC(?counter)
LIMIT 10
```

SPARQL - top 10 object types

type	counter
"crucks"@en	6646
"residential structures"@en	4765
"samples"@en	3382
"undetermined (information indicator)"@en	2867
"caulking compound"@en	2037
"plant components"@en	1605
"agricultural buildings"@en	1348
"timbers (wood by form)"@en	1237
"planks (wood)"@en	1104
"beams (structural elements)"@en	799



Record	Object	Sample		
Record data source			×	
Record ider	ntifier		×	
Record note contains			×	
Record refers to material				
Salix (ge	enus)		•	
Record refe	rs to date		×	
Record refers to object			×	
Record refers to sample			×	
RUN				

P:2001114 (domain: stichtingring.nl) (source: 'Results from search for 'Stichting RING' on DCCD site') Moerasbos Ypenburg 115610 (source: 'Göteborg 218, Nya Lödöse Gångtunnel vid Gamlestadstorget. Arkeologisk förundersökning i Göteborgs kommun') Johan Linderholm vid MAL har miljöarkeologiskt bedömt påträffade sediments poten ♥ 2141875 (source: 'Report on an Archaeological Investigation at Beverley Minster, East Yorkshire') One was accompanied by a willow rod and bead, and was covered by a wooden board; ♥ 2142009 (source: 'Report on an Archaeological Investigation at Beverley Minster, East Yorkshire') This burial was accompanied by two objects: a thin willow rod or wand (sf 232), ♥ 2142095 (source: 'Report on an Archaeological Investigation at Beverley Minster, East Yorkshire') The earliest datable objects comprise an Anglo-Saxon polychrome glass bead sf231	Results	Properties
115610 (source: 'Göteborg 218, Nya Lödöse Gångtunnel vid Gamlestadstorget.         Arkeologisk förundersökning i Göteborgs kommun')         Johan Linderholm vid MAL har miljöarkeologiskt bedömt påträffade sediments poten         ¥         2141875 (source: 'Report on an Archaeological Investigation at Beverley Minster, East Yorkshire')         One was accompanied by a willow rod and bead, and was covered by a wooden board;         2142009 (source: 'Report on an Archaeological Investigation at Beverley Minster, East Yorkshire')         This burial was accompanied by two objects: a thin willow rod or wand (sf 232),         2142095 (source: 'Report on an Archaeological Investigation at Beverley Minster, East Yorkshire')         This burial was accompanied by two objects: a thin willow rod or wand (sf 232),         2142095 (source: 'Report on an Archaeological Investigation at Beverley Minster, East Yorkshire')         The earliest datable objects comprise an Anglo-Saxon polychrome glass bead sf231	P:2001114 (c DCCD site') Moerasbos \	lomain: stichtingring.nl) (source: 'Results from search for 'Stichting RING' on 'penburg
2141875 (source: 'Report on an Archaeological Investigation at Beverley Minster, East Yorkshire')         One was accompanied by a willow rod and bead, and was covered by a wooden board;         ≥         2142009 (source: 'Report on an Archaeological Investigation at Beverley Minster, East Yorkshire')         This burial was accompanied by two objects: a thin willow rod or wand (sf 232),         ≥         2142095 (source: 'Report on an Archaeological Investigation at Beverley Minster, East Yorkshire')         This burial was accompanied by two objects: a thin willow rod or wand (sf 232),         ≥         2142095 (source: 'Report on an Archaeological Investigation at Beverley Minster, East Yorkshire')         The earliest datable objects comprise an Anglo-Saxon polychrome glass bead sf231	<u>115610</u> (sou Arkeologisk Johan Linder	rce: 'Göteborg 218, Nya Lödöse Gångtunnel vid Gamlestadstorget. förundersökning i Göteborgs kommun') holm vid MAL har miljöarkeologiskt bedömt påträffade sediments poten
2142009 (source: 'Report on an Archaeological Investigation at Beverley Minster, East Yorkshire') This burial was accompanied by two objects: a thin willow rod or wand (sf 232), 2142095 (source: 'Report on an Archaeological Investigation at Beverley Minster, East Yorkshire') The earliest datable objects comprise an Anglo-Saxon polychrome glass bead sf231	<u>2141875</u> (so Yorkshire') One was aco ¥	urce: 'Report on an Archaeological Investigation at Beverley Minster, East companied by a willow rod and bead, and was covered by a wooden board;
2142095 (source: 'Report on an Archaeological Investigation at Beverley Minster, East Yorkshire') The earliest datable objects comprise an Anglo-Saxon polychrome glass bead sf231	<u>2142009</u> (so Yorkshire') This burial w ¥	urce: 'Report on an Archaeological Investigation at Beverley Minster, East as accompanied by two objects: a thin willow rod or wand (sf 232),
*	<u>2142095</u> (so Yorkshire') The earliest ( ¥	urce: 'Report on an Archaeological Investigation at Beverley Minster, East datable objects comprise an Anglo-Saxon polychrome glass bead sf231

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Query Builder (query on left, results on right): Records referring to material "Salix (genus)" Shows English, Dutch & Swedish results, originating from NLP and database records

## Leveraging thesaurus structure

AAT hierarchical structure for concept 300012498 "wi	llow (wood)"		Refe	References to	References to wood in da	References to wood in datasets	References to wood in datasets (ar	References to wood in datasets (and	References to wood in datasets (and	References to wood in datasets (and
Materials Facet	aat:300264091		grey	grey literature)	grey literature) often use	grey literature) often use	grey literature) often use	grey literature) often use	grey literature) often use	grey literature) often use
- Materials (hierarchy name)	aat:300010357		mat	material/family	material/family/genus/sp	material/family/genus/species	material/family/genus/species	material/family/genus/species	material/family/genus/species	material/family/genus/species
materials (matter)	aat:300010358		inte	interchangeab	interchangeably	interchangeably	interchangeably	interchangeably	interchangeably	interchangeably
<materials by="" origin=""></materials>	aat:300206573		mee	interentingeau	interentingeably.	interentingedory.	inter changeabry.	interentingeabry.	inter enangeably.	interentingeasiy.
biological material	aat:300265629									
plant material	aat:300124117		For	For more effec	For more effective search	For more effective search emplo	For more effective search employ t	For more effective search employ the	For more effective search employ the	For more effective search employ the
<wood and="" products="" wood=""></wood>	aat:300011913		link	link between t	link between the materia	link between the material (type	link between the material (type of	link between the material (type of wo	link between the material (type of woo	link between the material (type of wood
wood (plant material)	aat:300011914		and	and the agent	and the agent (living orga	and the agent (living organism)	and the agent (living organism)	and the agent (living organism)	and the agent (living organism)	and the agent (living organism)
<wood by="" composition="" or="" origin=""></wood>	aat:300011915		anu	and the agent	and the agent (inving orga	and the agent (inving organism)	and the agent (inving organism)	and the agent (inving organism)	and the agent (inving organism)	and the agent (inving organism)
hardwood	aat:300011916		in A	in AAT this is a	in AAT this is a specific G	in AAT this is a specific GVP RT	in AAT this is a specific GVP RT	in AAT this is a specific GVP RT	in AAT this is a specific GVP RT	in AAT this is a specific GVP RT
willow (wood)	aat:300012498		spec	specialisation a	specialisation and its reci	specialisation and its reciprocal	specialisation and its reciprocal (in	specialisation and its reciprocal (inver	specialisation and its reciprocal (invers	specialisation and its reciprocal (inverse
black willow (wood)	aat:300012500		rola	rolationship o	rolationship o g	rolationship og :	rolationship o g	relationship o a :	relationship o.g.:	relationship o g
Japanese willow (wood)	aat:300012502		reia	relationship. e.	relationship. e.g	relationship. e.g	relationship. e.g	relationship. e.g	relationship. e.g	relationship. e.g
western black willow (wood)	aat:300012504									
white willow (wood)	aat:300012508		aat:	aat:300012498	aat:300012498 gvp:2841	aat:300012498 gvp:2841 derive	aat:300012498 gvp:2841 derived-	aat:300012498 gvp:2841 derived-	aat:300012498 gvp:2841 derived-	aat:300012498 gvp:2841 derived-
AAT Taxonomic structure for concept 300375384 (not a	formal Scientific	taxonomy)	mad ## "	made_from aa ## "willow (wo	made_from aat:3003753 ## "willow (wood)" deriv	made_from aat:300375384 . ## "willow (wood)" derived/mac	made_from aat:300375384 . ## "willow (wood)" derived/made-	made_from aat:300375384 . ## "willow (wood)" derived/made-fro	made_from aat:300375384 . ## "willow (wood)" derived/made-fror	made_from aat:300375384 . ## "willow (wood)" derived/made-from
Agents Facet	aat:300264089		"Sal	"Salix (genus)"	"Salix (genus)".	"Salix (genus)".	"Salix (genus)" .	"Salix (genus)".	"Salix (genus)".	"Salix (genus)".
- Living Organisms (hierarchy)	aat:300265673		aat:	aat:300375384	aat:300375384 gvp:aat28	aat:300375384 gvp:aat2842_sou	aat:300375384 gvp:aat2842_sourc	aat:300375384 gvp:aat2842_source_	aat:300375384 gvp:aat2842_source_f	aat:300375384 gvp:aat2842_source_for
living Organisms (entities)	aat:300390503		aat:	aat:300012498	aat:300012498 .	aat:300012498 .	aat:300012498 .	aat:300012498 .	aat:300012498 .	aat:300012498 .
Eukaryota (domain)	aat:300265677		## "	## "Salix (genu	## "Salix (genus)" source	## "Salix (genus)" source for "wi	## "Salix (genus)" source for "willo	## "Salix (genus)" source for "willow	## "Salix (genus)" source for "willow	## "Salix (genus)" source for "willow
Plantae (kingdom)	aat:300132360		1	/weed)"	(weed)	(wood)"	(weed)"	(weed)"		(wood)"
Angiospermae (division)	aat:300265706		(wo	(wooa) .	(wood) .	(wood) .	(wood) .	(WOOD) .	(WOOD) .	(WOOd) .
Magnoliopsida (class)	aat:300375593									
Malpighiales (order)	aat:300374936		A se	A search on e a	A search on e g "willow (	A search on e g "willow (wood)'	A search on e.g. "willow (wood)" c	A search on e g "willow (wood)" can	A search on e g "willow (wood)" can	A search on e.g. "willow (wood)" can
Salicaceae (family)	aat:300374937			retrieve the M	retrieve the Meterial feet	notrious the Material [act: 2000]	retrieve the Meterial [ast: 2000124	retrieve the Meterial [set:200012409	retrieve the Meterial [act;200012400]	retrieve the Meterial [act;200012400]
salix (genus)	aat:300375384		retri	retrieve the ivia	retrieve the Material laat	retrieve the Material [aat:30001	retrieve the Material [aat:3000124	retrieve the Material [aat:300012498]	retrieve the Material [aat:300012498],	retrieve the Material [aat:300012498],
salix lucida (species)	aat:300375387		the	the Agent [aat:	the Agent [aat:30037538	the Agent [aat:300375384] and	the Agent [aat:300375384] and the	the Agent [aat:300375384] and their	the Agent [aat:300375384] and their	the Agent [aat:300375384] and their
Salix lucida ssp caudata	aat:300375389		resp	respective hier	respective hierarchical de	respective hierarchical descenda	respective hierarchical descendant	respective hierarchical descendant	respective hierarchical descendant	respective hierarchical descendant
			cond	concepts.	concepts.	concepts.	concepts.	concepts.	concepts.	concepts.

## Leveraging thesaurus structure

	DN		-
Data integration case	study	r - query builder	
Record Object Sample		Results Properties	
Record data source Record identifier Record note contains Record refers to material pine (wood)	* * * *	302759 (source: 'Särskild arkeologisk undersökning inför muddringsarbeten i Valdemarsviken') Prov 5b:2 dateras till vinterhalvåret 1813/14 och utgör det enda provtagna spantvirket och furuvirket på fartyget som annars består av ekvirke mestadels komna från bordläggningen .	^
Record refers to date Record refers to object Record refers to sample	* * *	302762 (source: 'Särskild arkeologisk undersökning inför muddringsarbeten i Valdemarsviken') Proveniensen på det daterade furuvirket är norra Småland eller södra Östergötland.	
RUN		P:1995049 (domain: stichtingring.nl) (source: 'Results from search for 'Stichting RING' on DCCD site') Rotterdam, funderingshout P:1997020 (domain: stichtingring.nl) (source: 'Results from search for 'Stichting RING'	
		on DCCD site') Veeneiken Flevopolder A27/Hoge Vaart <u>P:1998080 (domain: stichtingring.nl)</u> (source: 'Results from search for 'Stichting RING' on DCCD site') Bleekveld Tiel, waterputten	~

Swedish records referring to aat:300012620 "pine (wood)", English records referring to aat:300343658 "Pinus (genus)" and Dutch records referring to aat:300343781 "Pinus sylvestris (species)"

- a hierarchical descendant of aat:300343658 "Pinus (genus)"



Record Object Sample	Results Properties
Object identifier *	type : Man-Made Object
Object type *	label : 581036
roofs •	is identified by : <u>581036</u>
Object note contains ×	is referred to by : Dendrochronological Analysis of Oak Timbers from Parham House,
Object made of material *	Storrington, near Pulborough, West Sussex, England
Object production date *	is referred to by : 581894
1504 AD to 1600 AD	has type : roofs
Object has sample ¥	has type : roofs
Object referenced by record *	has note : Together the evidence suggests that the construction of both the hall and
RUN	armoury roofs probably occurred between AD 1579 to AD 1580.
	was produced by : <u>581036</u>

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Query Builder: displaying properties of an individual result record



Record data source Record identifier Record note contains Record refers to material Record refers to date Record refers to object Object identifier Object type	* * * *		
Record identifier Record note contains Record refers to material Record refers to date Record refers to object Object identifier Object type	* * * *		
Record note contains Record refers to material Record refers to date Record refers to object Object identifier Object type	* * * *		
Record refers to material Record refers to date Record refers to object Object identifier Object type	* * *		
Record refers to date Record refers to object Object identifier Object type	* *		
Record refers to object Object identifier Object type	*		
Object identifier Object type			
Object type	¥		
Object type			
keels	٠		
Object note contains	×		
Object made of material			
Object production date			
Record refers to sample			
RUN			

Results	Properties		
<u>302714</u> (sou Valdemarsvi Kölen var av	irce: 'Särskild a iken') vek och kraftig.	rkeologisk undersökning inför muddringsarbeten i	*
<u>302682</u> (sou Valdemarsvi <sup>F</sup> ören var sp ¥	irce: 'Särskild a iken') betsig och akter	rkeologisk undersökning inför muddringsarbeten i n platt, med en akterspegel , som till synes gick hel	
<u>302713</u> (sou Valdemarsvi Vid akterstäv ¥	ırce: 'Särskild a iken') ven var det troli	rkeologisk undersökning inför muddringsarbeten i gt att bara kölen var bevarad då en genomgående kor	
P:1999019 ( DCCD site') Scheepswra	domain: stichtin ik Biddinghuize	ngring.nl) (source: 'Results from search for 'Stichting RING' on n T23	
P <u>:1999024 (</u> DCCD site') Scheepswra	<u>domain: stichtin</u> ik Dronten OK-i	ngring.nl) (source: 'Results from search for 'Stichting RING' on 84/2	
P:1994024 ( DCCD site')	domain: stichtin	ngring.nl) (source: 'Results from search for 'Stichting RING' on	•

#### Keels – results from Swedish and Dutch reports





ntifier e contains object entifier pe		* * * *		
e contains object entifier pe		* * *		
bject entifier pe		* *		
entifier pe		* *		
pe		*		
		•		
Object note contains				
Object made of material				
Fagus (genus)				
Object production date				
erenced by I	record	*		
	ade of mate ade of mate s (genus) roduction da erenced by r	ade of material s (genus) roduction date erenced by record		

Results         Properties           Keel 3 of 6, Starboardside, Back Rabbet	•
<u>1823</u> (source: 'Newport Medieval Ship') Keel 3 of 6, Starboardside, Back Rabbet	
<u>1824</u> (source: 'Newport Medieval Ship') Keel 3 of 6, Starboardside, Back Rabbet	
<u>1825</u> (source: 'Newport Medieval Ship') Keel 3 of 6, Starboardside, Back Rabbet	
<u>1826</u> (source: 'Newport Medieval Ship') Keel 3 of 6, Starboardside, Rabbet	
<u>1827</u> (source: 'Newport Medieval Ship') Keel 3 of 6, Starboardside, Rabbet	
<u>1828</u> (source: 'Newport Medieval Ship') Keel 3 of 6, Starboardside, Rabbet	
<u>2986</u> (source: 'Newport Medieval Ship') Nail - Keel/Garboard spike	
<u>3009</u> (source: 'Newport Medieval Ship') Core Sample for Fe Analysis	
	-

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Samples of beech wood keels

## Reflections

- Need to budget resources for significant data cleaning
- Pattern based mapping tool helped ensure validity and consistency of ontology mappings and lower level implementation details
- A GUI (or API) can shield end users from the need to fully understand ontological model and SPARQL syntax
- Operational projects should budget resources to locate key datasets and reports to address the research questions (addressing issues of access and permission).
- Metadata expressing the use case(s) for integration
- Metadata expressing major integration design decisions

## Reflections ctd.

- How much detail is it worthwhile to model?
- What is the appropriate balance of detail in application modeling between the ontology and the vocabulary side for the research questions?
  - Not go beyond original data semantics ... Depends on use cases
- →ISO 25964 Part 2 (ch21)

One of the fundamental purposes of an ontology is reasoning,

- ... Whereas the role of most of the vocabularies described in this part of ISO 25964 is to guide the selection of search/indexing terms, or the browsing of organized document collections, the purpose of ontologies in the context of retrieval is different. Ontologies are not designed for information retrieval by index terms or class notation, but for making assertions about individuals, e.g. about real persons or abstract things such as a process. ...
- Compare with earlier (STAR) case study with more detail in (CRM-EH) model and research questions ...

## STAR Demonstrator – search for a conceptual pattern

An Internet Archaeology publication on one of the (Silchester Roman) datasets we used in STAR discusses the finding of a *coin* within a *hearth*.

-- does the same thing occur in any of the grey literature reports?

Requires comparison of extracted data with NLP output



### **STAR Demonstrator** – search for a conceptual pattern Research paper reports finding a *coin in hearth* – exist elsewhere?



## Reflections on data integration (NLP)

- More work needed on the NLP extraction methods needed for an operational capability
- More work on Relation Extraction taking account of grammatical and use patterns in Dutch, Swedish reports
- However study able to generate CRM/AAT based RDF from English, Dutch and Swedish texts and demonstrate feasibility of semantic integration
- Identify passages in reports of particular relevance for information extraction (and also sections to avoid)?
- eg focus on the abstracts for overall subject metadata?

Reflections on data integration (NLP) ctd.

- How to semantically model NLP outcomes? Archaeological reports often refer to types of object or materials with the object implicit rather than referring to specific objects.
- Need for subject metadata that expresses provenance of (linked) data and the method by which it was generated. allowing a distinction to be made in search results between results extracted from data and via NLP
- Associate confidence levels with NLP derived data?

## References

- ARIADNE. <u>http://www.ariadne-infrastructure.eu</u>
- ARIADNE Portal. <u>http://portal.ariadne-infrastructure.eu/</u>
- Data Integration study Demonstrator. <u>http://ariadne-lod.isti.cnr.it/description.html</u>
- STELETO open source code. <u>https://github.com/cbinding/steleto/</u>

### **Related publications**

- Tudhope D, May K, Binding C, Vlachidis A. 2011. Connecting archaeological data and grey literature via semantic cross search. Internet Archaeology, 30, <u>https://doi.org/10.11141/ia.30.5</u>
- Binding C, Tudhope D, Vlachidis A. (2018) A study of semantic integration across archaeological data and reports in different languages. Journal of Information Science, Sage. <u>https://doi.org/10.1177/0165551518789874</u>

#### **Open Access** versions available from <u>https://bit.ly/2ocaHC6</u>

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