Explaining linguistic facts in a realist theory of word formation*

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The present paper examines foundational issues of a realist word-formation theory. A realist linguistic theory, as it is understood here, takes linguistic units and the linguistic systems that determine them to be abstract entities. With respect to such a word-formation theory, the following two questions are discussed:

1. What are the word-formation facts to be described and explained or predicted?
2. What linguistic objects are those word-formation facts about?

Presupposing the axiomatically formalised Pattern-and-Restriction Theory (PR), it is proposed that the word-formation facts to be described and explained or predicted are true statements of word-formation relations in the linguistic system under consideration, and that those facts are about abstract lexical units in the sense of the realist framework of Integrational Linguistics (IL). On the example of a word-formation pattern in some spoken Modern German system it is shown how deductive-nomological (D-N) explanations or predictions of word-formation facts can be logically derived from theorems of the PR theory and theorems of a grammar and a dictionary of the linguistic system.

1 Introduction

Katz and Postal (1991) distinguish three views of natural language: the *nominalist* view of language as concrete physical phenomena (linguistic performance in Chomskyan terms), the *conceptual* view of language as psychological phenomena (linguistic competence), and the *realist* view of language, which sees it as an abstract entity, underlying both linguistic competence and performance. In the latter view, "linguistics is an autonomous formal science with its own goals and domain of facts" (Katz and Postal 1991: 515). Taking this general view for granted, I shall examine in this paper what such a position means for a realist word-formation theory.

In particular, I shall discuss the two questions stated below:

1. What are the word-formation facts to be described and explained or predicted?
2. What linguistic objects are those word-formation facts about?

The following answers will be proposed here:

1. The word-formation facts to be described and explained or predicted are true statements of *word-formation relations* in the linguistic system under consideration.
2. Statements of word-formation relations in a linguistic system are about abstract *lexical units* in the system.

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By “statement”, I understand an abstract declarative sentence in some natural or formal language. Statements in this sense can be true or false of the objects they are about, given that they contain no explicit or implicit free variables. A true statement is a fact. As an example, consider the following, pretheoretic statement of a word-formation relation in Modern German systems:

(1) The noun *Fall* meaning ‘falling event’ is formed from the verb *fallen* meaning ‘to fall’ in Modern German.

This statement is about two lexical units in Modern German systems:

– a noun with the citation form *Fall* and a lexical meaning paraphrased as ‘falling event’;

– a verb with the citation form *fallen* and the lexical meaning ‘to fall’.

Implicitly, it will be argued, such a statement also involves a *word-formation process* – here: conversion – and an appropriate *word-formation pattern* by means of which formal, categorial, and semantic properties of the lexical units can be related. Insofar as the statement in (1) is true, it is a fact – a word-formation fact, to be exact.

The discussion of these questions and answers will be couched in terms of the *Pattern-and-Restriction Theory* (*PR*), which was developed and axiomatically formalised in Nolda (2012), a study on conversion in Modern German. PR aims at describing and explaining or predicting word-formation relations in a linguistic system, which underlie lexical motivation relations. In particular, the theory allows for explaining word-formation relations between conventionalised, ‘existing’ lexical units as well as for predicting word-formation relations also involving non-conventionalised, but still ‘possible’ lexical units. Lexical units are understood in the sense of the realist framework of *Integrational Linguistics* (*IL*) as abstract pairings of a paradigm and a lexical meaning (Lieb 1983, 1985, 2005). The finite set of conventionalised lexical units in a linguistic system – those which are ‘known’ by speakers of the corresponding idiolect, variety, or language – constitute the *vocabulary* of the system. As a rule, the vocabulary of a system is a proper subset of its *lexicon*, which also contains non-conventionalised lexical units and is potentially infinite, provided that word formation is recursive in the system.

According to the PR conception, word-formation relations between lexical units explicitly or implicitly involve word-formation processes and multidimensional word-formation patterns which each combine four *formation means*:

1. a *formal means*, which determines form-related properties,
2. a *paradigmatic means*, which determines paradigmatic categorial properties,
3. a *lexical means*, which determines lexical categorial properties, and
4. a *semantic means*, which determines semantic properties.

For every word-formation pattern, there is an associated *formation restriction* which accounts for distributional properties of the pattern.

Statements of word-formation relations in a linguistic system can be logically derived in PR from lawlike sentences – theorems of the word-formation theory – and particular statements concerning system-specific properties of the involved lexical units, processes, patterns, and restrictions. As I shall demonstrate in this paper, such a logical derivation represents a *deductive-nomological* (*D-N*)

explanation or *prediction* in the sense of Hempel (1965).[1] Roughly speaking, a word-formation relation exists between a lexical product and one or more lexical bases in the system if, and only if, product properties are obtained through the application of a word-formation pattern in the system to base properties in the associated formation restriction.

As a word-formation theory in the Item-and-Process tradition, PR is related to, and has been influenced by, theories such as Aronoff's (1976) theory of word-formation rules and morphological restrictions, Beard's (1995) Lexeme-Morpheme Base Morphology, and in particular Lieb's (2013) Process Model of Word Formation, another IL-based word-formation theory. Albeit being Item-and-Process with respect to word formation proper, understood as a component in the morphosyntactic part of linguistic systems, PR is Word-and-Paradigm as far as the lexicon is concerned, for which IL's Word-and-Paradigm notion of lexical units is presupposed. IL's axiomatically constructed theory of language has also influenced PR's axiomatic formalisation.[2]

The present paper is organised as follows. Section 2 outlines how lexical units are understood here, *i.e.* the objects statements of word-formation relations in PR are about. Word-formation relations and the involved word-formation processes and patterns are introduced in Section 3 on the example of conversion by means of a selected word-formation pattern in some spoken Modern German system. In Section 4 it is shown how statements of word-formation relations can be explained or predicted in PR. Section 5 concludes the discussion with a summary of the realist approach to word formation advocated here. An appendix lists the symbols used below as well as the presupposed axioms and definitions of PR's theoretical core. Despite the fact that all of the examples in this paper are taken from German, it should be clear that the argument made here is not restricted to systems of that language.

2 Lexical units

As proposed in the introduction, abstract lexical units in a linguistic system are the objects statements of word-formation facts in the system are about. Lexical objects come in several kinds. *Lexical words* are provided by the *word lexicon* of the system. The word lexicon contains the *word vocabulary* of the conventionalised, 'existing' lexical words in the system as a proper subset. In addition, the word lexicon contains non-conventionalised, but still 'possible' lexical words. In a linguistic system with a non-empty morphological component, there is also a *stem lexicon*, providing *lexical stems*. The conventionalised lexical stems in the system are members of its *stem vocabulary*. Besides word and stem vocabularies, linguistic systems typically have a *collocation vocabulary* containing conventionalised idiomatic or non-idiomatic *lexical word groups*. Besides conventionalised word groups, phrasal word formation (*i.e.* word formation based on groups) may in addition involve non-conventionalised word or stem groups as bases.

[1] Hempel's explication of the notion of (non-inductive, non-statistical) scientific explanation in terms of deductive-nomological explanation was much discussed in the subsequent literature, and pragmatic alternatives were proposed (for a thorough overview cf. Stegmüller 1983). For the sake of logical and expository simplicity, I shall stick to Hempel's classic conception here. This should not be mistaken as implying that PR is incompatible with alternative notions of scientific explanation.

[2] As a companion for word-formation description in PR, there is a computer program called "PPR" ("System for Processing Word-formation Patterns and Their Restrictions", available at http://andreas.nolda.org/software.html#ppr), which can be used for testing the soundness of theoretical and empirical hypotheses. Currently, it provides a small set of lexical entries and selected word-formation patterns for spoken and written Modern German systems, including the word-formation pattern used as an example here.

According to the IL theory of language, a lexical word is a pairing of a word paradigm and a lexical meaning. For lexical words, the following notation will be used in this paper:[3]

/ˈfal[ə]n/$^{\mathrm{W}}_{\text{‘to fall’}}$: pairing of a word paradigm with the citation form /ˈfal[ə]n/ and the lexical meaning ‘to fall’.

/ˈfal[ə]n/$^{\mathrm{W}}_{\text{‘to decrease’}}$: pairing of a word paradigm with the citation form /ˈfal[ə]n/ and the lexical meaning ‘to decrease’.

The monosemous lexical words /ˈfal[ə]n/$^{\mathrm{W}}_{\text{‘to fall’}}$ and /ˈfal[ə]n/$^{\mathrm{W}}_{\text{‘to decrease’}}$ correspond to the first two of nine major readings the *Wörterbuch der deutschen Gegenwartssprache* (Klappenbach and Steinitz 1980: vol. 2, 1204–1207) distinguishes in the lexical entry for this citation form. The lexical entry as a whole describes a polysemous *lexicological word* in the sense of Nolda (2012: sect. 4.3, 2016): a set of lexical words of the same part of speech with identical or overlapping paradigms and related lexical meanings.[4] For heuristic reasons, PR subscribes to the view that the objects of word-formation theory and word-formation description are monosemous lexical units, not potentially polysemous lexicological units, thereby reducing descriptive complexity. In the PR sense, then, word formation may be understood as the formation of lexical units.

A *word paradigm* – *i.e.* the paradigm of a lexical word – specifies the (spoken or written) *forms* of the word as well as the *paradigmatic categorisations* they realise. IL models paradigms as set-theoretic relations between forms and categorisations (Lieb 1983: chap. 6 and 11, 2005). In the paradigm of /ˈfal[ə]n/$^{\mathrm{W}}_{\text{‘to fall’}}$, the word form /ˈfal[ə]n/, for example, realises paradigmatic categorisations such as:[5]

(2) a. non-perfect, active, non-clausal infinitival verb form
b. first person, plural, indicative, present tense, non-perfect, active verb form

From a set-theoretic point of view, a paradigmatic categorisation is a set of *paradigmatic categories*:[6]

(3) a. {NonPerf-Vf, Act-Vf, NonClausInf-Vf}
b. {1Pers-Vf, Plur-Vf, Ind-Vf, Pres-Vf, NonPerf-Vf, Act-Vf}

Paradigmatic categories, in turn, are sets of forms. Categories of word forms are obtained on the basis of classification systems on the set of word forms in the linguistic system, and likewise for categories of stem forms (for the presupposed notion of classification system cf. Lieb 1993: chap. 9; a proposal for such classification systems in Modern German can be found in Nolda 2012: app. A).[7]

Lexical stems (in particular, stems of lexical words) are taken to be pairings of a stem paradigm and a lexical meaning in IL. Informally, lexical stems will be notated in the following way:

/ˈfal/$^{\mathrm{St}}_{\text{‘to fall’}}$: pairing of a stem paradigm with the citation form /ˈfal/ and the lexical meaning ‘to fall’.

[3] “/ˈfal[ə]n/” is an informal phonological notation for the form *fallen* in spoken Modern German. (For details, see below.)
[4] The term “lexicological word” is due to François Filandre. Similar distinctions are made by Cruse (1986: chap. 3) in terms of “lexical units” and “lexemes” and by Mel’čuk (1995: 206 f., 250) in terms of “lexical units” and “vocables”. The range of semantic relations which can hold between members of the same lexicological word are discussed by Blank (1997, 2003).
[5] Traditional tenses like ‘present tense’ or ‘present perfect’ are decomposed here into a proper tense category (present tense) and an anteriority category (non-perfect or perfect) (Nolda 2012: sect. 4.2.2, app. A; cf. also Teuber 2005; Thieroff and Vogel 2012). Non-clausal infinitival verb forms are infinitives without *zu* (‘nicht satzwertige’, ‘reine Infinitive’ in German grammatical tradition).
[6] The symbolic categories used in this paper and their intended readings are listed in the appendix.
[7] Paradigmatic categories are the paradigm-related subset of what is called *unit categories* or *type 1 categories* in IL.

/ˈfal/$^{\text{St}}_{\text{‘to decrease’}}$: pairing of a stem paradigm with the citation form /ˈfal/ and the lexical meaning ‘to decrease’.

As a rule, the lexical meaning of a lexical word is identical to the lexical meaning of its stem (if any).[8]

In analogy to lexicological words, Nolda (2012, 2016) also assumes potentially polysemous *lexicological stems*. Like lexicological words, they are not considered to be objects of word-formation theory or word-formation description.

A *stem paradigm* – the paradigm of a lexical stem – specifies the forms of the stem as well as the paradigmatic categorisations they realise. The categorisations the stem form /ˈfal/ realises in the paradigm of /ˈfal/$^{\text{St}}_{\text{‘to fall’}}$ include:[9]

(4) a. basic verb-stem form
b. infinitival verb-stem form
c. non-second-or-third-person-singular, indicative, present tense verb-stem form

In set-theoretic notation:

(5) a. {Basic-VStf}
b. {Inf-VStf}
c. {Non2/3PersSing-VStf, Ind-VStf, Pres-VStf}

In addition to basic and inflectional categorisations, the paradigm of /ˈfal/$^{\text{St}}_{\text{‘to fall’}}$ also assigns word-formation related categorisations to /ˈfal/ such as:

(6) a. compounding verb-stem form
b. conversion verb-stem form

(7) a. {Comp-VStf}
b. {Conv-VStf}

As a compounding stem form, /ˈfal/ can be used in the formation of compounding products like /ˈfal/ /ˌʃirm/$^{\text{St}}_{\text{‘parachute’}}$; as a conversion stem form, it is used in the formation of conversion products like /ˈfal/$^{\text{St}}_{\text{‘falling event’}}$. Note that word-formation stem forms need not coincide with inflectional ones, as in the case of the conversion stem forms /ˈflu:G/ and /ˈap/ /ˌflu:G/ of the verb stems /ˈfli:G/$^{\text{St}}_{\text{‘to fly’}}$ and /ˈap/ /ˌfli:G/$^{\text{St}}_{\text{‘to take off’}}$, respectively, which are used in the formation of the noun stems /ˈflu:G/$^{\text{St}}_{\text{‘flying event’}}$ and /ˈap/ /ˌflu:G/$^{\text{St}}_{\text{‘take-off event’}}$.[10] This example also shows that word-formation stem forms may be inherited by derivative lexical stems in the same way as inflection stems forms are. (For a discussion of compounding and derivation stem forms from a broader IL

[8] Examples of lexical words without corresponding stems are ‘nominalised adjectives’ in Modern German, such as the noun /ˈklain[ə]r/$^{\text{W}}_{\text{‘small person’}}$, which is directly formed from the adjective /ˈklain/$^{\text{W}}_{\text{‘small’}}$. The word paradigm of the former does not result from morphological inflection of a noun stem; rather, it is inherited from (a subset of) the word paradigm of the latter (for discussion cf. Nolda 2012: sect. 3.2.2 and 8.2).

[9] For the concept of *basic stem form* (or *Grundstammform*) cf. Fuhrhop (1998: 27, *passim*). In (4 c), there are no anteriority or voice categories involved: those categories are not marked morphologically in Modern German, but syntactically (*i.e.* by means of auxiliaries).

[10] According to the analysis proposed in Nolda (2012: sect. 5.1.2), the lexical stem /ˈap/ /ˌfli:G/$^{\text{St}}_{\text{‘to take off’}}$ has word-formation stem forms only. The word forms of the corresponding lexical word /ˈap/ /ˌfli:G[ə]n/$^{\text{W}}_{\text{‘to take off’}}$ are not formed from /ˈap/ /ˌfli:G/$^{\text{St}}_{\text{‘to take off’}}$ through morphological inflection, but from /ˈfli:G[ə]n/$^{\text{W}}_{\text{‘to fly’}}$ through syntactic derivation by means of prefixation of the particle form /ˈap/.

perspective cf. Fuhrhop 1998; Eisenberg 2013: chap. 6 and 7; conversion stem forms are introduced in Nolda 2012: chap. 3, 4, and 7.)

Word and stem forms are regarded in IL as sequences of *morphosyntactic atoms*: word forms are sequences of one or more *syntactic atoms* (*syntactic base forms* in IL terms) and stem forms are sequences of one or more *morphological atoms* (*morphological base forms*). In spoken linguistic systems, morphosyntactic atoms are phonological units.

PR as a theory of word formation (and, more recently, inflection) is, in principle, neutral with respect to questions of phonological representation. In this paper, I shall make the minimal assumption that phonological representations specify not only segmental phonological properties but also suprasegmental ones, in particular lexical accents of syllables. *Primary lexical accent* is understood in IL as the potential of a syllable for bearing a non-contrastive syntactic accent (Lieb 1999 a, 1999 b). In the informal phonological notation used here,[11] such accents are indicated by the usual IPA symbol "ˈ". The IPA symbol "ˌ" is used for *deaccented lexical accents* ('secondary lexical accents') in word forms like /ˈgastproˌfesor/ ('visiting professor') and /ˈgastprofeˌsoːr[ə]n/ ('visiting professors'), where they result from deaccentuation of the primary lexical accents in /proˈfesor/ and /profeˈsoːr[ə]n/, respectively.[12] Syllables with primary lexical accent will be called "accented syllables" for short. In order to keep the informal phonological notation as simple as possible, syllable borders are left unspecified, while atom borders are delimited by "/ /". In syllables with primary or deaccented lexical accents, the IPA symbol ":" is used to mark vowels which are phonetically realised as long tense ones, while unmarked vowels are phonetically realised as short lax ones. Phonologically the former may be analysed in Modern German as being 'smoothly cut' or 'in loose contact', and the latter as being 'abruptly cut' or 'in close contact', as proposed by Becker (1998), Restle (2003), and others. For phonetic realisations of vowels in syllables without primary or deaccented lexical accent cf. Becker (1998: 82–99). "[ə]" represents epenthetic schwa (for discussion cf. Wiese 2000: 106–114, 242–248). Capital letters like "G" stand for archiphonemic consonants which, in Modern German, are unspecified for voice (or tenseness) and are realised as voiced (or, for that matter, lax) consonants unless they undergo final devoicing (tensing) or spirantisation (cf. Lieb 1999 a: 374 f.).

Lexical meanings like 'to fall' are understood in IL as *(potential) concepts* – certain perceptual or conceptual properties involving attributes of concrete or abstract entities (Lieb 1983: chap. 13, 1985). For the sake of the argument, let us assume that the attribute TO-FALL is a three-place intensional relation whose name is defined in (8):

(8) *Definition (tentative)*
TO-FALL = the intensional relation between x_1, x_2, and x_3 such that x_1 is a movement process of x_2 and x_3 is a directional property such that 'x_2 moves downwards towards x_3 in x_1 through gravitational force'.

Then the name of the concept 'to fall' can be defined as follows:

(9) *Definition*
'to fall' = the property of being a perception or conception whose content contains the attribute TO-FALL.

Thus, 'to fall' is a concept denoting certain kinds of movement processes.

[11] This is also the phonological notation used in the user interface of PPR (cf. Note 2).

[12] As convincingly argued by Becker (1998: 82–84) for German, 'smoothly cut', phonetically long tense vowels in syllables without primary lexical accent require a deaccented lexical accent ('morphologischer Nebenakzent').

Lexical units are elements of *lexical categories* such as part-of-speech categories or lexical gender. The lexical word /ˈfal/$^{\text{W}}_{\text{‘falling event’}}$, for instance, realises a *lexical categorisation* with the following lexical categories:[13]

(10) noun, masculine nominal word

Again, lexical categorisations are modelled as sets of lexical categories:

(11) {Noun, Masc-N}

The corresponding lexical categorisation realised by the lexical stem /ˈfal/$^{\text{St}}_{\text{‘falling event’}}$ is:

(12) noun stem, stem of a masculine nominal word

Or, in set-theoretic notation:

(13) {NounSt, Masc-NSt}

Lexical categories of lexical words are obtained on the basis of a classification system on the word lexicon in the linguistic system, while lexical categories of lexical stems are based on a classification system on the stem lexicon.

3 Word-formation relations, processes, and patterns

In the PR view, the word-formation facts to be described and explained or predicted are statements of *word-formation relations* between lexical units in a linguistic system, underlying *lexical motivation relations*. Lexical motivation relations in a linguistic system relate a lexical unit to one or more lexical units it is ‘dependent’ upon in formal, categorial, and/or semantic respects (for an overview of lexical motivation cf. Marzo 2015). Let “**S**” be an ambiguous constant for some specific spoken Modern German system. Then there are motivation relations in **S** such as:

(14) /ˈfal[ə]n/$^{\text{W}}_{\text{‘to decrease’}}$ is motivated by /ˈfal[ə]n/$^{\text{W}}_{\text{‘to fall’}}$ in **S**.

(15) /ˈfal/$^{\text{W}}_{\text{‘falling event’}}$ is motivated by /ˈfal[ə]n/$^{\text{W}}_{\text{‘to fall’}}$ in **S**.

Implicitly, such motivation relations involve a motivating process:[14]

(16) /ˈfal[ə]n/$^{\text{W}}_{\text{‘to decrease’}}$ is motivated by /ˈfal[ə]n/$^{\text{W}}_{\text{‘to fall’}}$ through metaphor in **S**.

(17) /ˈfal/$^{\text{W}}_{\text{‘falling event’}}$ is motivated by /ˈfal[ə]n/$^{\text{W}}_{\text{‘to fall’}}$ through conversion in **S**.

Word-formation relations in the PR sense correspond to lexical motivation relations which are established through word-formation processes. They come in two kinds: *direct word-formation relations* and *indirect word-formation relations*. Basically, a direct word-formation relation involves lexical units which are directly related through the word-formation process by means of an appropriate word-formation pattern; an indirect word-formation relation, on the contrary, presupposes a direct word-formation relation between *lexically equivalent* units (*e.g.* the stems of the relata). As

[13] In Modern German, the set of masculine nominal words is not limited to nouns, but does also include masculine pronouns.

[14] In the case of (16), /ˈfal[ə]n/$^{\text{W}}_{\text{‘to decrease’}}$ may be motivated by /ˈfal[ə]n/$^{\text{W}}_{\text{‘to fall’}}$ through metaphorical comparison of, say, the decrease of temperature with the downward movement of liquid in a liquid-in-glass thermometer.

an example, consider the two statements of word-formation relations below, corresponding to the lexical motivation relation (17):[15]

(18) a. /ˈfal/$^{\text{W}}_{\text{‘falling event’}}$ is indirectly formed from /ˈfal[ə]n/$^{\text{W}}_{\text{‘to fall’}}$ through conversion in **S**.
b. /ˈfal/$^{\text{St}}_{\text{‘falling event’}}$ is directly formed from /ˈfal/$^{\text{St}}_{\text{‘to fall’}}$ through conversion in **S**.

As a shortcut, the following notation will be used for stating indirect and direct word-formation relations through conversion in **S**:

(19) a. /ˈfal/$^{\text{W}}_{\text{‘falling event’}} \lessdot^{\mathbf{S}}_{\text{conv}}$ /ˈfal[ə]n/$^{\text{W}}_{\text{‘to fall’}}$
b. /ˈfal/$^{\text{St}}_{\text{‘falling event’}} \leqslant^{\mathbf{S}}_{\text{conv}}$ /ˈfal/$^{\text{St}}_{\text{‘to fall’}}$

In such a notation, the lexical unit denoted by the term left of “$\lessdot$” is an *indirect (lexical) product* and the lexical units denoted by the term or terms right of “$\lessdot$” are *indirect (lexical) bases*. Similarly, the lexical unit denoted by the term left of “$\leqslant$” is a *direct (lexical) product* and the lexical units denoted by the term(s) right of “$\leqslant$” are *direct (lexical) bases*. In contexts where the distinction between direct and indirect word-formation relations is irrelevant, the familiar “$<$” is used for notating word-formation relations between products and bases:

(20) a. /ˈfal/$^{\text{W}}_{\text{‘falling event’}} <^{\mathbf{S}}_{\text{conv}}$ /ˈfal[ə]n/$^{\text{W}}_{\text{‘to fall’}}$
b. /ˈfal/$^{\text{St}}_{\text{‘falling event’}} <^{\mathbf{S}}_{\text{conv}}$ /ˈfal/$^{\text{St}}_{\text{‘to fall’}}$

Explicit word-formation relations, with explicit reference to a word-formation process, imply *implicit* word-formation relations without such a reference:

(21) a. /ˈfal/$^{\text{W}}_{\text{‘falling event’}}$ is indirectly formed from /ˈfal[ə]n/$^{\text{W}}_{\text{‘to fall’}}$ in **S**.
b. /ˈfal/$^{\text{St}}_{\text{‘falling event’}}$ is directly formed from /ˈfal/$^{\text{St}}_{\text{‘to fall’}}$ in **S**.

(22) a. /ˈfal/$^{\text{W}}_{\text{‘falling event’}} \lessdot^{\mathbf{S}}$ /ˈfal[ə]n/$^{\text{W}}_{\text{‘to fall’}}$
b. /ˈfal/$^{\text{St}}_{\text{‘falling event’}} \leqslant^{\mathbf{S}}$ /ˈfal/$^{\text{St}}_{\text{‘to fall’}}$

Although word-formation relations in this sense are *directional*, *i.e.* non-symmetric, relations, PR does not exclude cases where word-formation relations involve the same lexical units in different order. This may be considered, for example, for the following pairs of lexical units:[16]

(23) a. /ˈha:g[ə]l/$^{\text{W}}_{\text{‘hailing event’}} \lessdot^{\mathbf{S}}$ /ˈha:g[ə]ln/$^{\text{W}}_{\text{‘to hail’}}$
b. /ˈha:g[ə]l/$^{\text{St}}_{\text{‘hailing event’}} \leqslant^{\mathbf{S}}$ /ˈha:g[ə]l/$^{\text{St}}_{\text{‘to hail’}}$

(24) a. /ˈha:g[ə]ln/$^{\text{W}}_{\text{‘to hail’}} \lessdot^{\mathbf{S}}$ /ˈha:g[ə]l/$^{\text{W}}_{\text{‘hailing event’}}$
b. /ˈha:g[ə]l/$^{\text{St}}_{\text{‘to hail’}} \leqslant^{\mathbf{S}}$ /ˈha:g[ə]l/$^{\text{St}}_{\text{‘hailing event’}}$

Put differently, word-formation relations need not be asymmetric (cf. Eschenlohr 1999: sect. 3.1.2 and Nolda 2012: sect. 5.1.3 for discussion).

[15] Statements of word-formation relations of these kinds are inspired from the ‘word-formation statements’ in the Process Model of Word Formation (Lieb 2013).

[16] This presupposes that for both directions, there are appropriate word-formation processes and word-formation patterns, left implicit in (23) and (24).

Both implicit and explicit word-formation relations are based on *fully explicit* word-formation relations, not only specifying a word-formation process, but also an appropriate *word-formation pattern*, such as the one informally given in (27):

(25) a. /ˈfal/$^{\text{W}}_{\text{‘falling event’}}$ is indirectly formed from /ˈfal[ə]n/$^{\text{W}}_{\text{‘to fall’}}$ through conversion by means of (27) in **S**.

b. /ˈfal/$^{\text{St}}_{\text{‘falling event’}}$ is directly formed from /ˈfal/$^{\text{St}}_{\text{‘to fall’}}$ through conversion by means of (27) in **S**.

(26) a. /ˈfal/$^{\text{W}}_{\text{‘falling event’}} <^{\mathbf{S}}_{\text{conv((27))}}$ /ˈfal[ə]n/$^{\text{W}}_{\text{‘to fall’}}$

b. /ˈfal/$^{\text{St}}_{\text{‘falling event’}} <^{\mathbf{S}}_{\text{conv((27))}}$ /ˈfal/$^{\text{St}}_{\text{‘to fall’}}$

(27)

Formal means:	initial accentuation.
Paradigmatic means:	formation of a basic noun-stem form.
Lexical means:	formation of a noun stem in the masculine.
Semantic means:	formation of a concept according to the scheme ‘event consisting in a non-state denoted by the base meaning’.

(For the empirical motivation of (27) cf. Nolda 2012: sect. 7.2.) From a mathematical point of view, a *one-place* pattern like (27) with *one-place formation means* is a quadruple of simple or composed one-place set-theoretic operations:

(28) ⟨ini-acc,
basic-nstf,
masc-nst∘nounst,
event⟩

(“∘” denotes function composition.) Since Nolda (2012), I have generalised the theoretical core of PR in such a way as not only to account for word formation, but also for inflection. In order to do so, both word-formation patterns and inflection patterns are introduced as special cases of *formation patterns* which are quadruples of formation means of the kind illustrated above.[17]

Besides one-place patterns for *one-place* word-formation processes like conversion, derivation, shortening, or reduplication, PR also assumes patterns with at least two places for word-formation processes like compounding or blending. Generally speaking, n-place word-formation patterns with n-place formation means are used for describing or explaining statements of n-place word-formation relations between n lexical bases and one lexical product, involving n-place word-formation processes.

I shall now briefly discuss formal, paradigmatic, lexical, and semantic formation means on the example of pattern (28). *Formal means* operate on forms. The formal means of (28) accents the first

[17] Inflection patterns are distinguished from word-formation patterns with respect to their function. An inflection pattern is used to determine forms and their categorisations in the paradigm of a lexical unit l on the basis of forms and categorisations in the paradigms of one or more lexical units $l_1, \ldots, l_n$ such that l is lexically equivalent to at least one l_i ($1 \leq i \leq n$; $n > 1$ is needed for analytic inflection); l_i and l are lexically equivalent if they are identical or if one of them is a *morphological correspondence* of the other (*e.g.* its stem). As a consequence, lexical and semantic means of inflection patterns are the identity operation or other trivial operations. A word-formation pattern, on the contrary, is used to relate a lexical product to lexical bases which are not lexically equivalent to it. (Cf. Definition Schema 5, Definition 9, Definition 10, and Definition Schema 11 in the appendix.) This captures the traditional idea that word formation, but not inflection, ‘creates new words’.

stressable syllable in its arguments (basically, the first non-schwa syllable) and deaccents any other accented syllables (cf. Nolda 2012: sect. 3.1.3 and 7.2.1):[18]

(29) ini-acc (/ˌy:b[ə]r/ /ˈfal/) = /ˈy:b[ə]r/ /ˌfal/

In cases where the first stressable syllable is already accented, this operation amounts to the identity operation:

(30) a. ini-acc (/ˈfal/) = /ˈfal/
b. ini-acc (/ˈap/ /ˌflu:G/) = /ˈap/ /ˌflu:G/
c. ini-acc (/f[ə]r/ /ˈzu:x/) = /f[ə]r/ /ˈzu:x/

Syllables like /f[ə]r/ are unstressable in spoken Modern German. As can be seen from these examples, formal formation means are not limited in PR to *arrangement operations* like concatenation or affixation, but may also specify phonological properties by means of *phonological operations*, insofar as the latter are consequences of word formation.[19] Such a strategy is already considered by Anderson (1992: 224):

> With a shift in conception to a morphology based on Word Formation Rules, however, the motivation for such a class of mixed rules [*i.e.* morphologically conditioned phonological rules; A. N.] becomes much less secure. This is because it is generally possible to incorporate all of the phonological 'side effects' of a given category into the Word Formation Rule that creates the category in the first place.

Paradigmatic and *lexical means* operate on paradigmatic and lexical categorisations, respectively. In (28), the paradigmatic and lexical means are constant functions, assigning the same value to any argument:

(31) basic-nstf ({Conv-VStf}) = {Basic-NStf}

(32) masc-nst ∘ nounst ({VSt}) = masc-nst (nounst ({VSt}))
= masc-nst ({NounSt})
= {NounSt, Masc-NSt}

There are also paradigmatic and lexical inheritance functions, copying (one of) their argument(s) to the value. In Modern German systems, this is the case in the formation of 'right-headed' compounds.

Semantic means operate on concepts. The values of the semantic means of (28) are concepts denoting events (in the narrow sense of "event"), derived from concepts denoting arbitrary non-states:[20]

(33) event ('to fall') = 'falling event'

[18] Since formation means are set-theoretic, extensional operations, there are many equivalent ways of how to specify them. "ini-acc", for instance, is defined in Nolda (2012: sect. 7.2.1) as acc ∘ deacc, *i.e.* as a composed operation deaccenting all accented syllables in its arguments and then accenting their first stressable syllable. Such an operation is identical to an operation accenting the first stressable syllable and then deaccenting any other accented syllables. What matters in PR is which arguments and values are related by the means, not the way this is achieved. Thus, PR clearly is a declarative theory of word formation and inflection, and not a derivational or transformational one.

[19] This view is also taken by the Process Model of Word Formation (Lieb 2013), where 'construction modes' – the counterparts of PR's word-formation patterns (cf. Note 21 below) – include not only 'arrangement functions' and 'shortening functions', but also phonological 'form-change functions'.

[20] With Mourelatos (1978) I distinguish between *states* and *non-states*, the latter being classified into *processes* and *events*. Typically, events are discrete and telic, while processes may be homogeneous and atelic.

Those values are determined by means of a suboperation on the corresponding attributes, called "EVENT" in (34):

(34) EVENT (TO-FALL) = EVENT-OF-FALLING

(For definition and empirical discussion cf. Nolda 2012: sect. 7.2.2.)

Formation instances combine the arguments and values of the formal, paradigmatic, lexical, and semantic formation means of a formation pattern. (35) and (36) are examples for such quadruples:

(35) ⟨/ˈfal/,
{Conv-VStf},
{VSt},
'to fall'⟩

(36) ⟨/ˈfal/,
{Basic-NStf},
{NounSt, Masc-NSt},
'falling event'⟩

(35) and (36) *instantiate* the lexical units $/\text{ˈfal}/^{\text{St}}_{\text{'to fall'}}$ and $/\text{ˈfal}/^{\text{St}}_{\text{'falling event'}}$, in **S**, respectively. While the third and fourth components of a formation instances directly represent categorial and semantic properties of the instantiated lexical units, the first and second components represent formal and categorial properties of one of their forms. Note that the components in a formation instance may be underspecified with respect to the actual properties they represent. This holds in particular for the semantic component, which needs not be identical to the actual lexical meaning as long as it is implied by the latter (cf. Definition 1 in the appendix).

Word-formation processes in a linguistic system *S* like *conversion in S* (conv_S) are functions from patterns to *formation operations* on formation instances in *S*. In (37), for example, $\text{conv}_{\mathbf{S}}$ assigns a formation operation to the word-formation pattern (28) by means of which the *product instance* (36) can be formed from the *base instance* (35):

(37) $$\text{conv}_{\mathbf{S}}\left(\begin{array}{l}\langle\text{ini-acc},\\ \text{basic-nstf},\\ \text{masc-nst}\circ\text{nounst},\\ \text{event}\rangle\end{array}\right)\left(\begin{array}{l}\langle/\text{ˈfal}/,\\ \{\text{Conv-VStf}\},\\ \{\text{VSt}\},\\ \text{'to fall'}\rangle\end{array}\right) = \begin{array}{l}\langle\text{ini-acc}(/\text{ˈfal}/),\\ \text{basic-nstf}(\{\text{Conv-VStf}\}),\\ \text{masc-nst}\circ\text{nounst}(\{\text{VSt}\}),\\ \text{event}(\text{'to fall'})\rangle\end{array} = \begin{array}{l}\langle/\text{ˈfal}/,\\ \{\text{Basic-NStf}\},\\ \{\text{NounSt, Masc-NSt}\},\\ \text{'falling event'}\rangle\end{array}$$

The same holds, in principle, for inflection processes and inflection patterns. As a rule, an *n*-place *formation process* assigns an *n-place* formation operation to an *n*-place formation pattern.[21]

[21] Word-formation processes and formation operations in PR jointly correspond to the word-formation processes in the Process Model of Word Formation (Lieb 2013), from which they are inspired. There, a word-formation process in a linguistic system is conceived of as a 13-place function from a 'basic triple', an 'added triple', and a 'construction mode' to a 'result triple'. The triples – so-called 'fully specified forms' – correspond to PR's base instances, minus the lexical component. The 'construction mode', being a 7-tuple of five formal, one paradigmatic, and one semantic means, roughly corresponds to PR's word-formation patterns, without the lexical means. Note that all word-formation processes in the Process Model are two-place in PR's sense: in the case of derivation by means of affixation, the 'added triple' consists of an affix form, a more or less trivial paradigmatic categorisation, and the empty concept; in the case of conversion, its first and second components are further reduced to the empty set. For an in-depth comparison of PR with the Process Model cf. Lieb (2013: sect. 8).

For every formation pattern in a linguistic system, there is an associated *formation restriction* which accounts for distributional properties of the pattern by specifying logical or system-specific restrictions on the formation instances to which the corresponding formation operation may be applied.[22] PR models formation restrictions as set-theoretic entities. The formation restriction of the one-place pattern (28), for instance, is a set with the following elements:

(38) {⟨/ˈfal/,
{Conv-VStf},
{VSt},
'to fall'⟩,
⟨/ˌy:b[ə]r/ /ˈfal/,
{Conv-VStf},
{VSt},
'to raid'⟩,
⟨/ˈflu:G/,
{Conv-VStf},
{VSt},
'to fly'⟩,
⟨/ˈap/ /ˌflu:G/,
{Conv-VStf},
{VSt},
'to take off'⟩,
⟨/f[ə]r/ /ˈzu:x/,
{Conv-VStf},
{VSt},
'to try'⟩,
…}

Formation restrictions of two-place patterns are two-place extensional relations, and so on.

In a grammar of **S**, the formation restriction (38) can partially or totally be identified by a hypothesis of the following kind:[23]

(39) *Hypothesis (tentative)*
The formation restriction of pattern (28) in **S** is the set of all $\langle f, P, L, c\rangle$ in **S** for which the following conditions hold:

1. *P* contains Conv-VStf,
2. *L* contains VSt, and
3. *c* denotes a non-state.

[22] Formation restrictions of formation patterns in PR correspond to what Aronoff (1976: 36) calls "morphological restrictions on the sorts of words one may use as the base of certain WFRs [word-formation rules; A. N.]". Besides morphological conditions proper, formation restrictions in PR may specify any logical or system-specific condition relevant for the application of the pattern. (For the relation between formation restrictions and productivity cf. Note 26 in Section 4.)

[23] Being set-theoretic, extensional entities, formation restrictions can, in principal, be identified by various intensional criteria. That is, one and the same formation restriction may be identified by different logically or materially equivalent hypotheses. Thus, formation restrictions are independent from the form of their description. What is more, 'output-related' hypotheses on product instances in the range of a formation operation can be accounted for by 'input-related' restrictions on corresponding base instances in the domain of the formation operation.

Formation patterns and their associated formation restrictions are provided for by the *formation component* in the morphosyntactic part of the linguistic system (cf. Axiom 1, Definition 2, Definition Schema 3, Definition 4, and Definition Schema 5 in the appendix). Word-formation processes and word-formation relations, however, are not given by the system; rather, they are ultimately determined by the word-formation patterns in the system and their formation restrictions (cf. in particular Definition Schemes 13, 15, and 18; definitions of names of individual word-formation processes such as conversion, derivation, or compounding can be found in Nolda 2012: sect. 6.3, app. B).[24]

4 Explanation and prediction of statements of word-formation relations

Statements of word-formation relations between lexical units, explicitly or implicitly involving word-formation processes and word-formation patterns, can be explained or predicted in PR in terms of *deductive-nomological* (D-N) explanations or predictions. According to the classic definition in Hempel (1965), a *D-N explanation* is an argument with the following logical structure:

$$\text{(40)}\quad \frac{\begin{array}{c} C_1 \wedge C_2 \wedge \ldots \wedge C_k \\ L_1 \wedge L_2 \wedge \ldots \wedge L_r \end{array}}{E}$$

The variables used in (40) are interpreted in Hempel (1965: 336) as follows:

> Here, $C_1, C_2, \ldots, C_k$ are sentences describing the particular facts invoked; $L_1, L_2, \ldots, L_r$ are the general laws on which the explanation rests. Jointly these sentences will be said to form the *explanans* S […]. The conclusion E of the argument is a sentence describing the explanandum-phenomenon […].

Thus, read in bottom-up direction, an argument of the form (40) represents a D-N explanation of the *explanandum* E by an *explanans* consisting of *lawlike sentences* $L_1, L_2, \ldots, L_r$ ('general laws') and *particular statements* $C_1, C_2, \ldots, C_k$ ('sentences describing particular facts'; Hempel 1965: 336 f.). In opposite direction, such an argument represents a *D-N prediction* of E from $C_1, C_2, \ldots, C_k$ and $L_1, L_2, \ldots, L_r$ (Hempel 1965: 365 f.). *True* explanations or predictions are logically valid arguments and have a true explanans and a true explanandum (Hempel 1965: 338). True explananda are true statements of the phenomenon to be explained, *i.e.* facts.

As examples for explananda in PR, consider the statements of word-formation relations in (41), already mentioned in Section 3 above and repeated here for convenience:

(41) a. $/\text{ˈfal}/^{\text{W}}_{\text{'falling event'}} \lessdot^{\mathbf{S}} /\text{ˈfal[ə]n}/^{\text{W}}_{\text{'to fall'}}$

b. $/\text{ˈfal}/^{\text{St}}_{\text{'falling event'}} \lessdot^{\mathbf{S}} /\text{ˈfal}/^{\text{St}}_{\text{'to fall'}}$

(41 a) states an indirect word-formation relation between the lexical words $/\text{ˈfal}/^{\text{W}}_{\text{'falling event'}}$ and $/\text{ˈfal[ə]n}/^{\text{W}}_{\text{'to fall'}}$ in some specific spoken Modern German system **S**, and (41 b) states a direct word-formation relation between the corresponding lexical stems $/\text{ˈfal}/^{\text{St}}_{\text{'falling event'}}$ and $/\text{ˈfal}/^{\text{St}}_{\text{'to fall'}}$ in **S**. I shall show now how to construct D-N explanations of these explananda in PR, starting with (41 b) and then turning to (41 a).

[24] "Conversion in S" ("conv_S"), for example, is defined in Nolda (2012: sect. 6.3.3, app. B) as a one-place word-formation process – *i.e.* a function from one-place word-formation patterns to one-place formation operations – whose arguments have a formal formation means that does not change segmental properties of its arguments. A somewhat different possibility would be to define it negatively as a one-place word-formation process whose arguments are not arguments of other one-place word-formation processes like derivation, shortening, or reduplication.

A lawlike sentence that can be used in the explanans of an explanation of (41 b) is the following one:

(42) *Theorem*
For every l, l_1, and S, if:

1. l and l_1 are lexical units in S and
2. there is an $\langle f, P, L, c\rangle$, $\langle f_1, P_1, L_1, c_1\rangle$, $\langle \varphi^1, \pi^1, \lambda^1, \sigma^1\rangle$, and ρ^1 such that:
   a. $\langle f, P, L, c\rangle$ and $\langle f_1, P_1, L_1, c_1\rangle$ instantiate l and l_1 in S, respectively,
   b. $\langle f_1, P_1, L_1, c_1\rangle$ is in the formation restriction of $\langle \varphi^1, \pi^1, \lambda^1, \sigma^1\rangle$ in S,
   c. ρ^1 is a one-place word-formation process in S,
   d. $\langle \varphi^1, \pi^1, \lambda^1, \sigma^1\rangle$ is in the domain of ρ^1, and
   e. $\rho^1(\langle \varphi^1, \pi^1, \lambda^1, \sigma^1\rangle)(\langle f_1, P_1, L_1, c_1\rangle) = \langle f, P, L, c\rangle$,

then $l \preccurlyeq^S l_1$.

This is a valid theorem of PR which follows from axioms and definitions of PR's theoretical core, listed in the appendix (cf. in particular Axiom Schema 3 and Definition Schemes 15, 16, and 17 as well as the axioms and definitions presupposed there; for the intended variable interpretations cf. the appendix, too). Put in a nutshell, the theorem stated in (42) amounts to the following: a lexical unit l is directly formed from a lexical unit l_1 in a linguistic system S if a formation instance $\langle f, P, L, c\rangle$ instantiating l can be formed in S through a one-place word-formation process ρ^1 by means of an appropriate one-place word-formation pattern $\langle \varphi^1, \pi^1, \lambda^1, \sigma^1\rangle$ from a formation instance $\langle f_1, P_1, L_1, c_1\rangle$ instantiating l_1 in the formation restriction of the pattern.

In (37) in Section 3 it was illustrated how a formation instance instantiating $/\text{ˈfal}/^{\text{St}}_{\text{‘falling event’}}$ is formed from a formation instance instantiating $/\text{ˈfal}/^{\text{St}}_{\text{‘to fall’}}$ in **S**. There, the following entities were involved:

1. a one-place word-formation process in **S**, conversion in **S** ($\text{conv}_{\mathbf{S}}$);
2. a word-formation pattern in **S**, repeated here as (43);
3. a formation instance instantiating $/\text{ˈfal}/^{\text{St}}_{\text{‘to fall’}}$ in **S** in the formation restriction of pattern (43), repeated here as (44);
4. a formation instance instantiating $/\text{ˈfal}/^{\text{St}}_{\text{‘falling event’}}$ in **S**, repeated here as (45).

(43) ⟨ini-acc,
basic-nstf,
masc-nst∘nounst,
event⟩

(44) ⟨/ˈfal/,
{Conv-VStf},
{VSt},
‘to fall’⟩

(45) ⟨/ˈfal/,
{Basic-NStf},
{NounSt, Masc-NSt},
‘falling event’⟩

With reference to these entities specific to the linguistic system **S**, the following states of affairs can be stated as potential theorems following from identificational sentences in a grammar and a dictionary of **S**:[25]

(46) a. *Theorem*
/ˈfal/$^{\text{St}}_{\text{‘falling event’}}$ and /ˈfal/$^{\text{St}}_{\text{‘to fall’}}$ are lexical units in **S**.

b. *Theorem*
(44) and (45) instantiate /ˈfal/$^{\text{St}}_{\text{‘to fall’}}$ and /ˈfal/$^{\text{St}}_{\text{‘falling event’}}$ in **S**, respectively.

c. *Theorem*
(44) is in the formation restriction of (43) in **S**.

d. *Theorem*
$\text{conv}_{\mathbf{S}}$ is a one-place word-formation process.

e. *Theorem*
(43) is in the domain of $\text{conv}_{\mathbf{S}}$.

f. *Theorem*
$\text{conv}_{\mathbf{S}}$ ((43)) ((44)) = (45).

These theorems, corresponding to the clauses in the antecedent in (42), will function as particular statements in the explanans of our explanation of (41 b).

We can now logically derive the explanandum (41 b) from the explanans (46) and (42) as follows:

(47)
$$\frac{\begin{array}{c}\text{particular statements (46)}\\ \text{lawlike sentence (42)}\end{array}}{\text{statement (41 b)}}$$

Basically, this argument takes the form of *modus ponens*: (42) is a universal implication whose antecedent and consequent parts are instantiated by (46) and (41 b), respectively, where variables are replaced by system-specific constants. Being a logically valid argument, (47) represents a D-N explanation (or, for that matter, as a D-N prediction) of the explanandum (41 b). Provided that (41 b) is a true statement – a fact – and that the explanans is true, too, (47) is a true explanation (or a true prediction) of a word-formation fact: the fact that there is a direct word-formation relation between the lexical stems /ˈfal/$^{\text{St}}_{\text{‘falling event’}}$ and /ˈfal/$^{\text{St}}_{\text{‘to fall’}}$ in **S**.

In a similar way, the statement in (41 a) of an indirect word-formation relation between the corresponding lexical words /ˈfal/$^{\text{W}}_{\text{‘falling event’}}$ and /ˈfal[ə]n/$^{\text{W}}_{\text{‘to fall’}}$ can be explained. For this explanandum, the following PR theorem can be used as a lawlike sentence in the explanans:

(48) *Theorem*
For every l, l_1, and S, if there is an l' and l'_1 such that:
1. l' and l'_1 are morphological correspondences of l and l_1 in S, respectively, and
2. $l' \lessdot^S l'_1$,

then $l <^S l_1$.

This theorem follows again from PR's theoretical core, listed in the appendix (cf. Definition Schemes 18, 19, and 20 as well as the definitions presupposed there). It states, roughly, that a lexical unit l is indirectly formed from a lexical unit l_1 in a linguistic system S if there is a direct word-formation relation between lexical units l' and l'_1 in S such that l' is a morphological correspondence

[25] As argued for in Budde (2000) from an IL perspective, it is the task of linguistic theory to provide definitions for general linguistic terms, whose extensions are identified by system-specific theories, such as a grammar or a dictionary.

of l in S and l'_1 is a morphological correspondence of l_1 in S. A lexical stem l' is a morphological correspondence of a lexical word l in a system S if l' is the stem of l in S (cf. Definition 9 in the appendix).

This lawlike sentence is again a universal implication. Instantiations of its antecedent, with variables replaced by system-specific constants, will function as particular statements in the explanans of our explanation of the explanandum (41 a). These should be theorems of a grammar and a dictionary of the specific linguistic system **S**:

(49) a. $/\text{ˈfal}/^{\text{St}}_{\text{`falling event'}}$ and $/\text{ˈfal}/^{\text{St}}_{\text{`to fall'}}$ are morphological correspondences of $/\text{ˈfal}/^{\text{W}}_{\text{`falling event'}}$ and $/\text{ˈfal[ə]n}/^{\text{W}}_{\text{`to fall'}}$ in **S**, respectively.

b. $/\text{ˈfal}/^{\text{St}}_{\text{`falling event'}} \preccurlyeq^{\mathbf{S}} /\text{ˈfal}/^{\text{St}}_{\text{`to fall'}}$

Note that (49 b) is identical to (41 b), the statement of a direct word-formation relation between $/\text{ˈfal}/^{\text{St}}_{\text{`falling event'}}$ and $/\text{ˈfal}/^{\text{St}}_{\text{`to fall'}}$ which was explained above.

As before, the explanandum (41 a) can be logically derived from the explanans (49) and (48) in an argument in basically *modus ponens* form:

(50)
$$\frac{\begin{array}{c}\text{particular statements (49)}\\ \text{lawlike sentence (48)}\end{array}}{\text{statement (41 a)}}$$

This argument represents again a D-N explanation (or a D-N prediction) of the explanandum. Insofar as the explanandum and the explanans are true, we have arrived at a true explanation (or a true prediction) of the word-formation fact that there is an indirect word-formation relation between the lexical words $/\text{ˈfal}/^{\text{W}}_{\text{`falling event'}}$ and $/\text{ˈfal[ə]n}/^{\text{W}}_{\text{`to fall'}}$ in **S**, which is based on the word-formation fact that there is a direct word-formation relation between the lexical stems $/\text{ˈfal}/^{\text{St}}_{\text{`falling event'}}$ and $/\text{ˈfal}/^{\text{St}}_{\text{`to fall'}}$ in **S**.

Explanations of statements of word-formation relations between lexical units $l, l_1, \ldots, l_n$ in a linguistic system S answer questions of the sort: Why is l formed from $l_1, \ldots, l_n$ in S? Typically, such questions pertain to conventionalised, 'existing' lexical units in the vocabulary of S. Predictions of such statements, however, answer questions like: Which l may be formed from $l_1, \ldots, l_n$ in S? Here, also non-conventionalised, but still 'possible' lexical units in the lexicon of S are relevant, provided that the word-formation pattern is not totally unproductive.[26] This even holds for the pattern in (43), which is occasionally used in Modern German to form non-conventionalised nouns like $/\text{ˈtsupf}/^{\text{W}}_{\text{`plucking event'}}$, from verbs like $/\text{ˈtsupf[ə]n}/^{\text{W}}_{\text{`to pluck'}}$ (cf. Rapp 2006: 425 for more examples):

(51) *dem allerletzten Zupf* *an der Saite*
the very.last plucking.event at the string
(*St. Galler Tagblatt* 75, 2008: 45; cited from the German Reference Corpus)

As mentioned in the introduction, "statement" is understood here as an abstract declarative sentence. Abstract sentences are, by definition, non-observable. What is more, the entities statements of word-formation relations explicitly or implicitly involve are abstract, too: lexical units, linguistic systems, word-formation processes, and word-formation patterns. Sentences like these, however, may figure in sentences about spatiotemporal, observable entities, for instance: speaker s of an idiolect

[26] In the PR view, productivity is not a question of the word-formation patterns themselves but rather of their *actuation* in the sense of Koefoed and Marle (2000). In particular, the productivity of a certain word-formation pattern may be independent of its formation restriction (the *morphological domain* in the sense of Koefoed and Marle 2000; for discussion cf. Becker 1990: sect. 3.7).

determined by system S behaves at place p and time t in a way by which s expresses that s believes that l is formed from $l_1, \ldots, l_n$ in S. A sentence of this form might describe, for example, some observed behaviour of a subject in a psycholinguistic experiment which examines word-formation relations in the system of a certain language or variety to which the idiolect spoken by the subject belongs. Sentences of this kind can, of course, themselves be explananda of D-N explanations or predictions. An appropriate lawlike sentence for the explanans could be a sentence stating that such a state of affairs is to be expected if l is formed from $l_1, \ldots, l_n$ in S and if certain further (psychological or methodological) conditions are fulfilled. One of the particular statements of the explanans would then be a statement of the word-formation relation in question – in a similar way as statement (41 b) of a direct word-formation relation (itself explained in (47)) functions as a particular statement in the explanans in (50), the explanation provided above for statement (41 a) of an indirect word-formation relation.

5 Summary and conclusions

The present paper discussed foundational issues of a realist word-formation theory, which takes linguistic units and the linguistic systems that determine them to be abstract entities, underlying both linguistic competence and performance. The discussion was couched in terms of the axiomatically formalised Pattern-and-Restriction Theory (PR) on the example of a selected word-formation pattern in some spoken Modern German system. It was proposed that the word-formation facts to be described and explained or predicted are true statements of word-formation relations between abstract lexical units in the linguistic system under consideration. Word-formation relations, underlying lexical motivation relations, involve one lexical product and one or more lexical bases as well as – explicitly or implicitly – a word-formation process and a word-formation pattern. It was shown how statements of word-formation relations can be explained or predicted in terms of deductive-nomological (D-N) explanations or predictions by logically deriving them from general theorems of the word-formation theory and system-specific theorems of a grammar and a dictionary of the linguistic system. Those theorems concern properties of lexical units, word-formation processes, word-formation patterns, and their associated formation restrictions. Lexical units are understood in the sense of the realist framework of Integrational Linguistics (IL) as abstract pairings of a paradigm and a lexical meaning. Conventionalised, 'existing' lexical units in a linguistic system, 'known' by speakers of the corresponding idiolect, variety, or language, as well as non-conventionalised, but still 'possible' lexical units are given by the lexicon of the system. Word-formation patterns as well as inflection patterns and the associated formation restrictions are provided for by the formation component in the morphosyntactic part of the system, while word-formation processes and word-formation relations are ultimately determined by the word-formation patterns in the system and their formation restrictions.

Since lexical units are given independently from word formation, word-formation relations between them can be identified in word-formation description by only partially specifying formal, categorial, and semantic properties of lexical bases and products in terms of word-formation patterns and formation restrictions. Thus, word-formation description in PR, such as in the word-formation part of a system-specific grammar, basically amounts to stating word-formation patterns and hypotheses about their associated formation restrictions (hence the theory's name). In addition, this realist word-formation theory does not restrict the objects word-formation facts are about to conventionalised lexical units, nor does it exclude word-formation relations through processes by means of more or less unproductive patterns from consideration. Thereby word-formation theory

and word-formation description can account both for the formation of 'existing' lexical units and for the potential formation of 'new' lexical units. Both accounts are, according to Aronoff (1976: 1), tasks of (word-formation) morphology:[27]

> It [morphology; A. N.] is […] concerned with words which are not simple signs, but which are made up of more elementary ones. This concern encompasses two distinct but related matters: first, the analysis of existing composite words, and second, the formation of new composite words. A unified theory of morphology should be capable of dealing with both of these areas in a unified and coherent manner […].

PR, I hope to have shown, is such a theory.

Appendix

List of symbols

Notational conventions:

"St": lexical stem.
"^{W}": lexical word.

Symbols for categories:

"1Pers-Vf": first person verb form.
"Act-Vf": active verb form.
"Basic-NStf": basic noun-stem form.
"Basic-VStf": basic verb-stem form.
"Comp-VStf": compounding verb-stem form.
"Conv-VStf": conversion verb-stem form.
"Ind-Vf": indicative verb form.
"Ind-VStf": indicative verb-stem form.
"Inf-VStf": infinitival verb-stem form.
"Masc-N": masculine nominal word.
"Masc-NSt": stem of a masculine nominal word.
"Non2/3PersSing-VStf": non-second-or-third-person-singular verb-stem form.
"NonClausInf-Vf": non-clausal infinitival verb form.
"NonPerf-Vf": non-perfect verb form.
"Noun": noun.
"NounSt": noun stem.
"Plur-Vf": plural verb form.
"Pres-Vf": present tense verb form.
"Pres-VStf": present tense verb-stem form.
"VSt": verb stem.

[27] As a matter of fact, PR is a theory of word formation (and inflection) in morphology *and* syntax, situating the formation component of a linguistic system in its morphosyntactic part. In this view, which is also shared by the Process Model of Word Formation (Lieb 2013), morphological word formation is the direct formation of lexical stems, while syntactic word formation is the direct formation of lexical words, such as the formation of 'nominalised adjectives' in Modern German like /ˈklain[ə]r/$^{W}_{\text{'small person'}}$ (cf. Note 8 in Section 2 above).

Symbols for relations, functions, and operations:

"$<$": word-formation relation.
"$\leqslant$": direct word-formation relation.
"$\lessdot$": indirect word-formation relation.
"$\circ$": function composition.

"basic-nstf": formation of a basic noun-stem form.
"conv": conversion.
"event": formation of a concept according to the scheme 'event consisting in a non-state denoted by the base meaning'.
"ini-acc": initial accentuation.
"masc-nst": formation of a stem of a masculine nominal word.
"nounst": formation of a noun stem.

Variables:

"B^n": non-empty n-place relations between $\langle f_1, P_1, L_1, c_1\rangle, \ldots, \langle f_n, P_n, L_n, c_n\rangle$ (in particular, n-place formation restrictions).
"c": (potential) concepts.
"f": sequences of morphological or syntactic atoms.
"F^n": non-empty one-place functions from entities $\langle \varphi^n, \pi^n, \lambda^n, \sigma^n\rangle$ to relations B^n (in particular, functions from formation patterns to formation restrictions).
"l": pairings of a paradigm and a concept.
"L": sets of non-empty sets of entities l (in particular, paradigmatic categorisations of entities l).
"n": natural numbers ≥ 1.
"P": sets of non-empty sets of entities f (in particular, paradigmatic categorisations of entities f).
"R^n": n-place relations between entities l (in particular, n-place word-formation relations).
"S": linguistic systems.
"K": sets of functions F^n (with arbitrary n).
"β^n": n-place operations on entities $\langle f, P, L, c\rangle$ (in particular, n-place formation operations).
"λ^n": n-place operations on entities L (in particular, n-place lexical formation means).
"π^n": n-place operations on entities P (in particular, n-place paradigmatic formation means).
"ρ^n": one-place functions from entities $\langle f, P, L, c\rangle$ to entities β^n (in particular, n-place word-formation processes).
"σ^n": n-place operations on entities c (in particular, n-place semantic formation means).
"φ^n": n-place operations on entities f (in particular, n-place formal formation means).

Ambiguous constant:

"**S**": some specific spoken Modern German system.

Axiomatic formalisation

Below are listed the axioms and definitions from the theoretical core of PR on the basis of which the theorems used for explaining statements of word-formation relations in Section 4 are derived. This is part of a revised and generalised version of the formalisation of PR in Nolda (2012: app. A).[28]

Definition 1
$\langle f, P, L, c\rangle$ *instantiates* l in S if, and only if:

1. f is a form of l in S or a citation variant of such a form,
2. P is a categorisation of f in the paradigm of l in S or a subset of such a categorisation,
3. L is a categorisation of l in S or a subset of such a categorisation, and
4. c is the meaning of l or a concept implied by that meaning.

Axiom 1
For every S, the morphosyntactic part of S contains exactly one component K such that, for every n, there is at most one F^n in K.

Definition 2
The *formation component* of S = the component in the morphosyntactic part of S according to Axiom 1.

Definition Schema 3
F^n is the *n-place formation foundation* in S if, and only if, F^n is in the formation component of S.

Definition 4
B^n is the *formation restriction* of $\langle\varphi^n, \pi^n, \lambda^n, \sigma^n\rangle$ in S if, and only if, $\langle\langle\varphi^n, \pi^n, \lambda^n, \sigma^n\rangle, B^n\rangle$ is in the n-place formation foundation in S.

Axiom Schema 2
For every B^n, $\langle f_1, P_1, L_1, c_1\rangle, \ldots, \langle f_n, P_n, L_n, c_n\rangle$, $\langle\varphi^n, \pi^n, \lambda^n, \sigma^n\rangle$, and S, if

1. B^n is the formation restriction of $\langle\varphi^n, \pi^n, \lambda^n, \sigma^n\rangle$ in S and
2. $\langle\langle f_1, P_1, L_1, c_1\rangle, \ldots, \langle f_n, P_n, L_n, c_n\rangle\rangle$ is in B^n,

then there is an $l_1, \ldots, l_n$ such that:

3. $\langle f_1, P_1, L_1, c_1\rangle, \ldots, \langle f_n, P_n, L_n, c_n\rangle$ instantiate $l_1, \ldots, l_n$ in S, respectively.

Definition Schema 5
$\langle\varphi^n, \pi^n, \lambda^n, \sigma^n\rangle$ is an *n-place formation pattern* in S if, and only if, there is a B^n such that B^n is the formation restriction of $\langle\varphi^n, \pi^n, \lambda^n, \sigma^n\rangle$ in S.

Definition Schema 6
$\langle\varphi^n, \pi^n, \lambda^n, \sigma^n\rangle$ is *applicable* to $\langle f_1, P_1, L_1, c_1\rangle, \ldots, \langle f_n, P_n, L_n, c_n\rangle$ if, and only if:

1. $\langle f_1, \ldots, f_n\rangle$ is in the domain of φ^n,
2. $\langle P_1, \ldots, P_n\rangle$ is in the domain of π^n,
3. $\langle L_1, \ldots, L_n\rangle$ is in the domain of λ^n, and
4. $\langle c_1, \ldots, c_n\rangle$ is in the domain of σ^n.

[28] This concerns in particular its generalisation for inflection (cf. Note 17 above).

Definition 7
The *operation specified by* $\langle \varphi^n, \pi^n, \lambda^n, \sigma^n \rangle$ = that β^n for which the following holds:

1. β^n is an n-place operation on entities $\langle f, P, L, c \rangle$ and
2. for every $\langle f_1, P_1, L_1, c_1 \rangle, \ldots, \langle f_n, P_n, L_n, c_n \rangle$:
   a. $\langle \langle f_1, P_1, L_1, c_1 \rangle, \ldots, \langle f_n, P_n, L_n, c_n \rangle \rangle$ is in the domain of β^n if, and only if, $\langle \varphi^n, \pi^n, \lambda^n, \sigma^n \rangle$ is applicable to $\langle f_1, P_1, L_1, c_1 \rangle, \ldots, \langle f_n, P_n, L_n, c_n \rangle$ and
   b. if $\langle \langle f_1, P_1, L_1, c_1 \rangle, \ldots, \langle f_n, P_n, L_n, c_n \rangle \rangle$ is in the domain of β^n, then the following holds: $\beta^n(\langle f_1, P_1, L_1, c_1 \rangle, \ldots, \langle f_n, P_n, L_n, c_n \rangle) = \langle \varphi^n(f_1, \ldots, f_n), \pi^n(P_1, \ldots, P_n), \lambda^n(L_1, \ldots, L_n), \sigma^n(c_1, \ldots, c_n) \rangle$.

Definition Schema 8
β^n is an *n-place formation operation* in S if, and only if, there is an n-place formation pattern $\langle \varphi^n, \pi^n, \lambda^n, \sigma^n \rangle$ in S such that β^n is the operation specified by $\langle \varphi^n, \pi^n, \lambda^n, \sigma^n \rangle$.

Definition 9
l' is a *morphological correspondence* of l in S if, and only if, l' is the stem or another morphological variant of l in S.

Definition 10
l is *lexically equivalent* to l' in S if, and only if:

1. $l = l'$,
2. l is a morphological correspondence of l' in S, or
3. l' is a morphological correspondence of l in S.

Definition Schema 11
$\langle \varphi^n, \pi^n, \lambda^n, \sigma^n \rangle$ is an *n-place word-formation pattern* in S if, and only if:

1. $\langle \varphi^n, \pi^n, \lambda^n, \sigma^n \rangle$ is an n-place formation pattern in S, and
2. for every $\langle \langle f_1, P_1, L_1, c_1 \rangle, \ldots, \langle f_n, P_n, L_n, c_n \rangle \rangle$ in the domain of the operation β^n specified by $\langle \varphi^n, \pi^n, \lambda^n, \sigma^n \rangle$, there is an $l, l_1, \ldots, l_n$ such that:
   a. $\beta^n(\langle f_1, P_1, L_1, c_1 \rangle, \ldots, \langle f_n, P_n, L_n, c_n \rangle), \langle f_1, P_1, L_1, c_1 \rangle, \ldots, \langle f_n, P_n, L_n, c_n \rangle$ instantiate $l, l_1, \ldots, l_n$ in S, respectively, and
   b. l is not lexically equivalent to l_1 or … or l_n in S.

Definition Schema 12
ρ^n is an *n-place formation process* in S if, and only if:

1. ρ^n is a non-empty one-place function from n-place formation patterns in S to n-place formation operations in S and
2. for every $\langle \varphi^n, \pi^n, \lambda^n, \sigma^n \rangle$ in the domain of ρ^n, $\rho^n(\langle \varphi^n, \pi^n, \lambda^n, \sigma^n \rangle)$ is the operation specified by $\langle \varphi^n, \pi^n, \lambda^n, \sigma^n \rangle$.

Definition Schema 13
ρ^n is an *n-place word-formation process* in S if, and only if:

1. ρ^n is an n-place formation process in S and
2. the domain of ρ^n is a set of n-place word-formation patterns in S.

Axiom Schema 3
For every $\langle f_1, P_1, L_1, c_1\rangle, \ldots, \langle f_n, P_n, L_n, c_n\rangle$, ρ^n, $\langle \varphi^n, \pi^n, \lambda^n, \sigma^n\rangle$, and S, if:

1. ρ^n is an n-place formation process in S,
2. $\langle \varphi^n, \pi^n, \lambda^n, \sigma^n\rangle$ is in the domain of ρ^n, and
3. $\langle\langle f_1, P_1, L_1, c_1\rangle, \ldots, \langle f_n, P_n, L_n, c_n\rangle\rangle$ is in the formation restriction of $\langle \varphi^n, \pi^n, \lambda^n, \sigma^n\rangle$ in S,

then there is an $\langle f, P, L, c\rangle$ and l such that:

4. $\langle f, P, L, c\rangle$ instantiates l in S and
5. $\rho^n(\langle \varphi^n, \pi^n, \lambda^n, \sigma^n\rangle)(\langle f_1, P_1, L_1, c_1\rangle, \ldots, \langle f_n, P_n, L_n, c_n\rangle) = \langle f, P, L, c\rangle$.

Definition Schema 14
$\langle f, P, L, c\rangle$ *can be formed* from $\langle f_1, P_1, L_1, c_1\rangle, \ldots, \langle f_n, P_n, L_n, c_n\rangle$ through ρ^n by means of $\langle \varphi^n, \pi^n, \lambda^n, \sigma^n\rangle$ in S if, and only if:

1. ρ^n is an n-place formation process in S,
2. $\langle \varphi^n, \pi^n, \lambda^n, \sigma^n\rangle$ is in the domain of ρ^n,
3. $\langle\langle f_1, P_1, L_1, c_1\rangle, \ldots, \langle f_n, P_n, L_n, c_n\rangle\rangle$ is in the formation restriction of $\langle \varphi^n, \pi^n, \lambda^n, \sigma^n\rangle$ in S, and
4. $\rho^n(\langle \varphi^n, \pi^n, \lambda^n, \sigma^n\rangle)(\langle f_1, P_1, L_1, c_1\rangle, \ldots, \langle f_n, P_n, L_n, c_n\rangle) = \langle f, P, L, c\rangle$.

Definition Schema 15
l is *directly formed* from $l_1, \ldots, l_n$ through ρ^n by means of $\langle \varphi^n, \pi^n, \lambda^n, \sigma^n\rangle$ in S ($l \lessdot^S_{\rho^n(\langle \varphi^n, \pi^n, \lambda^n, \sigma^n\rangle)} l_1 + \cdots + l_n$) if, and only if:

1. $l, l_1, \ldots, l_n$ are lexical units in S,
2. ρ^n is an n-place word-formation process in S, and
3. there is an $\langle f, P, L, c\rangle, \langle f_1, P_1, L_1, c_1\rangle, \ldots, \langle f_n, P_n, L_n, c_n\rangle$ such that:
   a. $\langle f, P, L, c\rangle, \langle f_1, P_1, L_1, c_1\rangle, \ldots, \langle f_n, P_n, L_n, c_n\rangle$ instantiate $l, l_1, \ldots, l_n$ in S, respectively, and
   b. $\langle f, P, L, c\rangle$ can be formed from $\langle f_1, P_1, L_1, c_1\rangle, \ldots, \langle f_n, P_n, L_n, c_n\rangle$ through ρ^n by means of $\langle \varphi^n, \pi^n, \lambda^n, \sigma^n\rangle$ in S.

Definition Schema 16
l is *directly formed* from $l_1, \ldots, l_n$ through ρ^n in S ($l \lessdot^S_{\rho^n} l_1 + \cdots + l_n$) if, and only if, there is a $\langle \varphi^n, \pi^n, \lambda^n, \sigma^n\rangle$ such that $l \lessdot^S_{\rho^n(\langle \varphi^n, \pi^n, \lambda^n, \sigma^n\rangle)} l_1 + \cdots + l_n$.

Definition Schema 17
l is *directly formed* from $l_1, \ldots, l_n$ in S ($l \lessdot^S l_1 + \cdots + l_n$) if, and only if, there is a ρ^n such that $l \lessdot^S_{\rho^n} l_1 + \cdots + l_n$.

Axiom Schema 4
For every $l, l_1, \ldots, l_n$, and S, if $l \lessdot^S l_1 + \cdots + l_n$, then:

1. l is a lexical stem or word in S and
2. $l_1, \ldots, l_n$ are lexical stems, stem groups, words, or word groups in S.

Axiom Schema 5
For every $l, l_1, \ldots, l_n$, and S, if:

1. $l \lessdot^S l_1 + \cdots + l_n$ and
2. l is a lexical word in S,

then $l_1, \ldots, l_n$ are lexical words or word groups in S.

Definition Schema 18
l is *indirectly formed* from $l_1, \ldots, l_n$ through ρ^n by means of $\langle \varphi^n, \pi^n, \lambda^n, \sigma^n \rangle$ in S ($l \leqslant^S_{\rho^n(\langle \varphi^n, \pi^n, \lambda^n, \sigma^n \rangle)} l_1 + \cdots + l_n$) if, and only if, there is an $l', l'_1, \ldots, l'_n$ such that:

1. $l, l_1, \ldots, l_n$ are lexically equivalent to $l', l'_1, \ldots, l'_n$ in S, respectively,
2. $l \neq l'$ or $l_1 \neq l'_1$ or ... or $l_n \neq l'_n$, and
3. $l' \leqslant^S_{\rho^n(\langle \varphi^n, \pi^n, \lambda^n, \sigma^n \rangle)} l'_1 + \cdots + l'_n$.

Definition Schema 19
l is *indirectly formed* from $l_1, \ldots, l_n$ through ρ^n in S ($l \leqslant^S_{\rho^n} l_1 + \cdots + l_n$) if, and only if, there is a $\langle \varphi^n, \pi^n, \lambda^n, \sigma^n \rangle$ such that $l \leqslant^S_{\rho^n(\langle \varphi^n, \pi^n, \lambda^n, \sigma^n \rangle)} l_1 + \cdots + l_n$.

Definition Schema 20
l is *indirectly formed* from $l_1, \ldots, l_n$ in S ($l \leqslant^S l_1 + \cdots + l_n$) if, and only if, there is a ρ^n such that $l \leqslant^S_{\rho^n} l_1 + \cdots + l_n$.

Definition Schema 21
l is *formed* from $l_1, \ldots, l_n$ through ρ^n by means of $\langle \varphi^n, \pi^n, \lambda^n, \sigma^n \rangle$ in S ($l <^S_{\rho^n(\langle \varphi^n, \pi^n, \lambda^n, \sigma^n \rangle)} l_1 + \cdots + l_n$) if, and only if:

1. $l \leqslant^S_{\rho^n(\langle \varphi^n, \pi^n, \lambda^n, \sigma^n \rangle)} l_1 + \cdots + l_n$ or
2. $l <^S_{\rho^n(\langle \varphi^n, \pi^n, \lambda^n, \sigma^n \rangle)} l_1 + \cdots + l_n$.

Definition Schema 22
l is *formed* from $l_1, \ldots, l_n$ through ρ^n in S ($l <^S_{\rho^n} l_1 + \cdots + l_n$) if, and only if, there is a $\langle \varphi^n, \pi^n, \lambda^n, \sigma^n \rangle$ such that $l <^S_{\rho^n(\langle \varphi^n, \pi^n, \lambda^n, \sigma^n \rangle)} l_1 + \cdots + l_n$.

Definition Schema 23
l is *formed* from $l_1, \ldots, l_n$ in S ($l <^S l_1 + \cdots + l_n$) if, and only if, there is a ρ^n such that $l <^S_{\rho^n} l_1 + \cdots + l_n$.

Definition 24
R^n is a *direct word-formation relation* in S if, and only if, there is a ρ^n such that $R^n = \{\langle l, l_1, \ldots, l_n \rangle \mid l \leqslant^S_{\rho^n} l_1 + \cdots + l_n\}$.

Definition 25
R^n is an *indirect word-formation relation* in S if, and only if, there is a ρ^n such that $R^n = \{\langle l, l_1, \ldots, l_n \rangle \mid l \leqslant^S_{\rho^n} l_1 + \cdots + l_n\}$.

Definition 26
R^n is a *word-formation relation* in S if, and only if, there is a ρ^n such that $R^n = \{\langle l, l_1, \ldots, l_n \rangle \mid l <^S_{\rho^n} l_1 + \cdots + l_n\}$.

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