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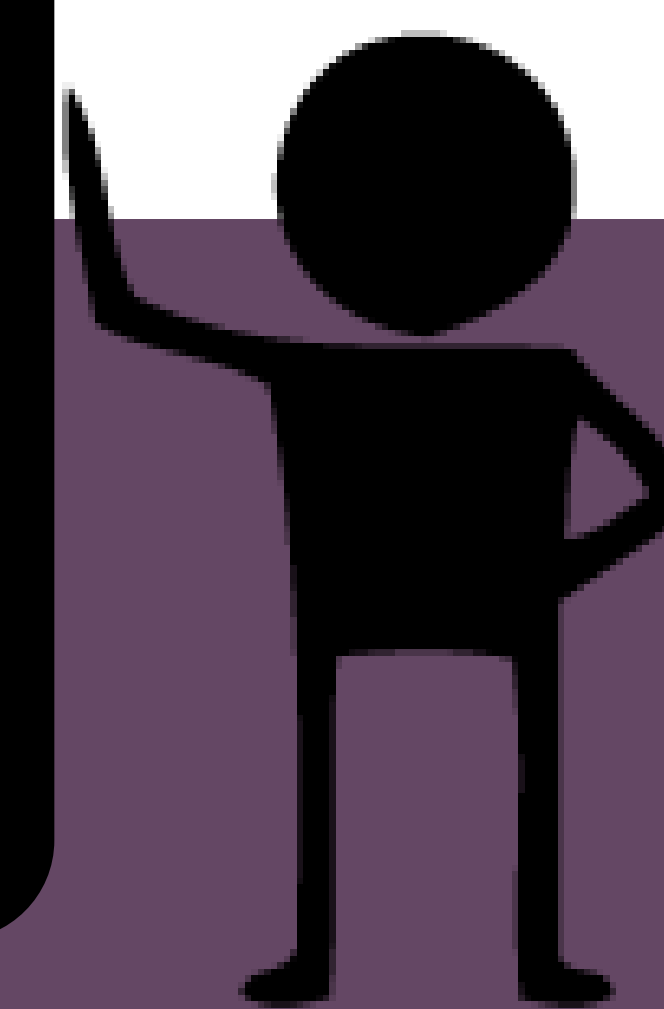
Subcommittee on Polymer Terminology (SPT)

# Basic Classification and Definitions of Polymerization Reactions

Chin Han Chan, Jiun-Tai Chen, Wesley S. Farrell, Christopher M. Fellows, Daniel J. Keddie, Christine K. Luscombe, Jan Merna, Graeme Moad, Gregory T. Russell, Patrick Théato, Paul D. Topham, Lydia Sosa Vargas

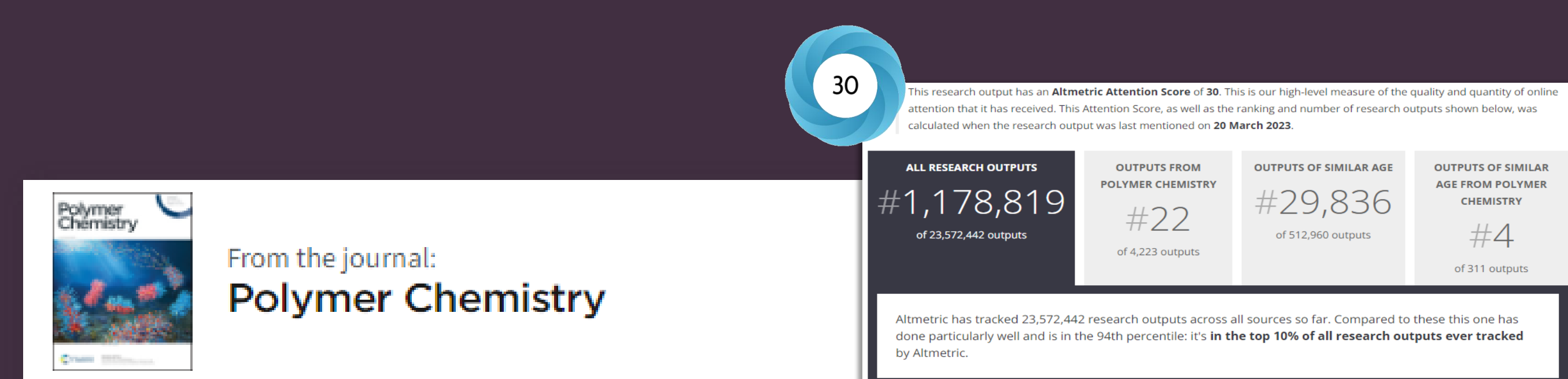
PROJECT: 2019-027-1-400

PROJECT CHAIR: John Matson



## Can we come up with clearer & more self-consistent terminology?

Before proposing new terms, the project members reached out to the Polymer community via a "dilemma document" in Polymer Chemistry (RSC journal) with the intention to outline the problem in the terminology used.



From the journal: **Polymer Chemistry**

### Reconsidering terms for mechanisms of polymer growth: the "step-growth" and "chain-growth" dilemma

Chin Han Chan, <sup>a</sup> Jiun-Tai Chen, <sup>b</sup> Wesley S. Farrell, <sup>c</sup> Christopher M. Fellows, <sup>d,e</sup> Daniel J. Keddie, <sup>f</sup> Christine K. Luscombe, <sup>g</sup> John B. Matson, <sup>h</sup> Jan Merna, <sup>i</sup> Graeme Moad, <sup>j</sup> Gregory T. Russell, <sup>k</sup> Patrick Théato, <sup>l</sup> Paul D. Topham <sup>m</sup> and Lydia Sosa Vargas <sup>n</sup>

Check for updates

Editorial Marc A. Hillmyer

Macromolecules 2022, 55, 11, 4175–4176

In this Perspective article, the goal was also to seek suggestions from the community on how to provide clear, simple, and consistent terms.

- Historical overview of terminology
- Study of terms in textbooks
- Language/translation issues
- Other exceptions (polymerisation mechanisms)

This article is part of the themed collections:

- Chemistry of polymers - Chemical Science symposium collection
- Polymer Chemistry Recent HOT Articles
- Polymer Chemistry Most Popular 2022



The project (and article) was also presented at the MACRO 22 conference in Winnipeg by project chair **John Matson**.

The talk's slides were made available for other SPT members to present in future occasions, like:

**Jan Merna**, at the 2023 Colloquium of the Institute of Macromolecular chemistry, University of Chemistry and Technology, in Prague; and **Greg Russell**, in his 3rd year UG Chemistry course at the University of Canterbury.

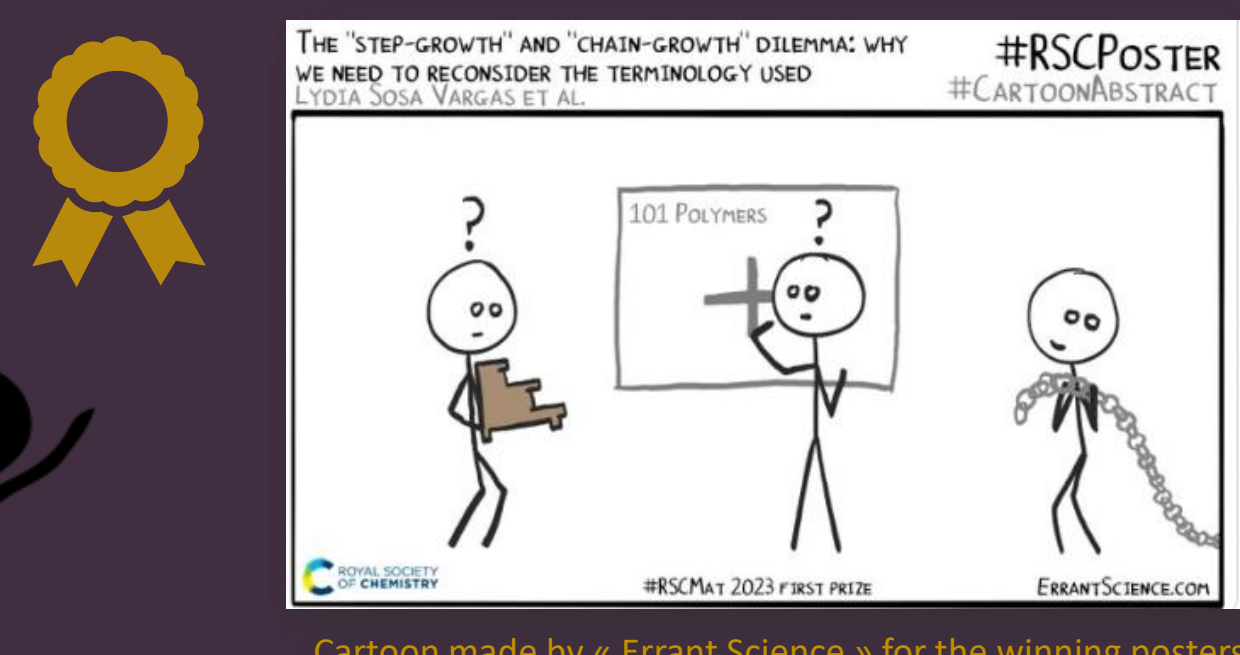
The **RSC poster event** was held on the Twitter platform on **February 28<sup>th</sup>** and lasted 24 hrs. During this time, the community interacted through messages to **discuss** the content, **ask** questions, **make** suggestions, etc.

**Malika Jeffries-EL** @Chem\_Diva · Feb 28  
I agree with this message, we need to rethink the usage of those terms.

**byebye** @polymerreaction · Mar 1  
I think the most important thing is to get rid of addition termination. The term makes from today's perspective no sense and doesn't distinguish anything

**Francesca Lorandi** @FrancescaLoran2 · Mar 1  
Thanks for sharing this! I agree that sometimes this becomes confusing, particularly the point about chains... And also with different languages - I teach this in Italian and it works fine when you just explain the concepts, but when starting with mechanism it can get confusing!

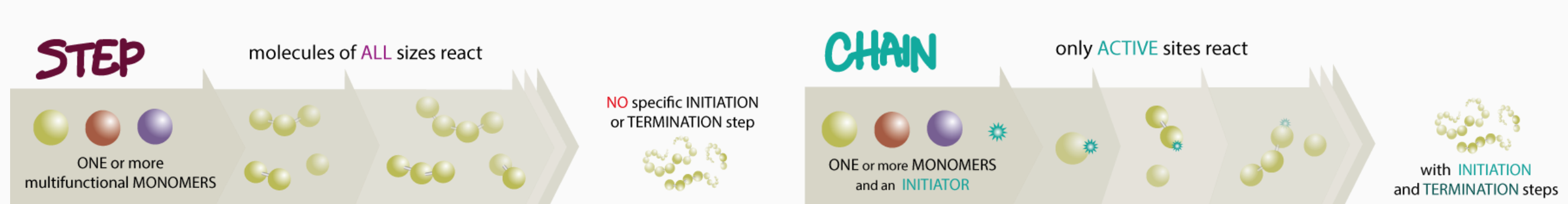
Engagement with the chemistry community was quite successful, (>20,000 impressions, >1000 engagements, >100♥, >30 retweets) bringing more visibility to the article and relaunching the discussion.



The poster was awarded the **1<sup>st</sup> prize** for the Materials category.

## PROJECT AIM

The terms "step-growth polymerization" and "chain-growth polymerization" are used widely to describe the two main polymerization mechanisms. However, both mechanisms require series of (elementary) steps AND both produce polymer chains!



This project aims to update the 1994 BASIC CLASSIFICATION AND DEFINITIONS OF POLYMERIZATION REACTIONS\* document to address these concerns in the context of existing trends in polymer synthesis.

## The SPT at the #RSC Poster competition

### The "step-growth" and "chain-growth" dilemma: why we need to reconsider the terminology used

Chin Han Chan, Jiun-Tai Chen, Wesley S. Farrell, Christopher M. Fellows, Daniel J. Keddie, Christine K. Luscombe, John B. Matson, Jan Merna, Graeme Moad, Gregory T. Russell, Patrick Théato, Paul D. Topham, Lydia Sosa Vargas

**The problem: STEP vs CHAIN**

The terms "step-growth polymerization" and "chain-growth polymerization" are used widely to describe the two main polymerization mechanisms. However, both mechanisms require series of (elementary) steps AND both produce polymer chains!

We are concerned that these terms are confusing because they do not describe the fundamental differences in the growth of polymers by these methods. So...

Can we come up with clearer & more self-consistent terminology?

### IUPAC recommendations

The IUPAC Subcommittee on Polymer Terminology (SPT) aims to provide guidance and recommendations on issues of terminology and nomenclature related to polymers. Two recommendations by the SPT were published in 1974, and 1994. The latter suggested the use of four more comprehensive terms; however, some issues still remain.

growth mechanism	MONOMERS reacting with ACTIVE polymer chains	MOLECULES of all sizes reacting
reaction type	chain reaction	usually non-chain reaction
WITH low-molar-mass byproducts	CONDENSATIVE CHAIN POLYMERIZATION	POLYCONDENSATION
WITHOUT low-molar-mass byproducts	CHAIN POLYMERIZATION	POLYADDITION

- The terms **polycondensation** and **polyaddition** sound very similar to the terms "condensation polymerization" and "addition polymerization", proposed by Carothers nearly a century ago, but these pairs are not synonyms.
- A **chain polymerization** (as defined in 1994) is a series of addition reactions, while **polyaddition** has a limited definition that **excludes** chain polymerization.
- The function of the term chain polymerization as both a **generic term** and a **specific term** is confusing, since for "step-growth" type mechanisms, no generic term has been proposed.
- All forms of polymerization generate polymer chains, but the term **chain polymerization** might be taken to imply that only such polymerizations do so, and that **polyaddition** and **polycondensation** do not.

### Use in textbooks

An analysis of terms used historically and in current books was particularly illuminating; despite a clear understanding for many decades of the two types of basic mechanisms of polymer growth, we as a community still have not agreed on terms to describe these two cases.

We examined the terms used in approximately **40 textbooks**, including multiple editions of some. This allowed us to gauge the influence of the definitions recommended by SPT in 1994 over time.

<ul style="list-style-type: none"> <li>Addition or chain-growth</li> <li>Condensation or step-growth</li> <li>Addition polymerization</li> <li>Condensation polymerization</li> </ul>	<ul style="list-style-type: none"> <li>Condensation polymers</li> <li>Condensation polymers</li> <li>Step-reaction polymerization</li> <li>Step-growth polymerization</li> </ul>	<ul style="list-style-type: none"> <li>Chain-reaction</li> <li>Condensation</li> <li>Chain-growth polymerization</li> </ul>
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### Lost in translation?

The term "step-growth" creates problems in languages where it is translated as "stair-growth", which is even more confusing than the English term!

The present use of similar-sounding terms with different meanings adds to the confusion, and this lack of clear and logical terminology causes problems in translating the terms from English into other languages.

**We need your INPUT!**

As a group of polymer scientists, we are working to find a solution. We welcome input from the community as we attempt to remedy these dilemmas. Please let us know your thoughts by emailing us at: [polymerterminology@iupac.org](mailto:polymerterminology@iupac.org)

Provide an **umbrella term** that captures the current IUPAC endorsed terms of **polycondensation** and **polyaddition**.

Provide a similar structure, including an **umbrella term**, for **chain polymerizations** that encompasses those **with** and **without** condensates.

Suggest terms for reactions that generate **polymers** but currently cannot be classified using any of the existing polymerization terms.

### Historical overview

- 1929** W.G. Carothers first to recognize the mechanistic distinction
- Q1939** R.G.W. Norrish, E. F. Brookman elucidated the mechanism of CHAIN POLYMERIZATION
- 1947** Otto Bayer introduced POLYADDITION
- 1952** IUPAC SPT created
- 1953** R. J. Flory published book: Principles of polymer chemistry
- 1967** R. Lenz publishes book: Organic Chemistry of Synthetic High Polymers
- 1974** first SPT recommendation (Definition of terms "addition polymerization" & "condensation polymerization")
- 1994** second SPT recommendation (The terms: polyaddition, polycondensation and chain polymerization, condensative chain polymerization were recommended)
- 2019** SPT project: Basic Classification and Definitions of Polymerization Reactions

