Chapter 16
Future directions?

Yet all experience is an arch wherethro'
Gleams that untravelled world, whose margin fades
Forever and forever when I move.

from 'Ulysses', by Alfred Lord Tennyson

We have now come to the end of our description of this intricate structure. We hope to have shown how it fits together and allows a new approach to algebraic topology, based on filtered spaces and homotopically defined functors on such structured spaces, and in which some nonabelian information in dimension 2 and the actions of the fundamental groupoid are successfully taken into account. We also wanted to convey how a key to the success of the theory has been the good modelling of the geometry by the algebra, and the way the algebra gives power and reality to some basic intuitions, revealing underlying processes.

We have presented the material in a way which we hope will convince you that the intricacy of the justification of the theory does not detract from the fact that crossed complexes theory are usable as a tool even without knowing exactly why they work. That is, we have given a pedagogical order rather than a logical and structural order. It should be emphasised that the order of discovery followed the logical order! The conjectures were made and verified in terms of ω-groupoids, and we were amazed that the theory of crossed complexes, which was in essence already available, fitted with this so nicely.

It is also surprising that this corpus of work followed from a simple aesthetic question posed in 1964–65, to find a determination of the fundamental group of the circle which avoided the detour of setting up covering space theory. This led to nonabelian cohomology, [Bro65a], and then to groupoids, [Bro67]. The latter suggested the programme of seeing how much could be done of a rewriting of homotopy theory replacing the word 'group' by 'groupoid', and if so whether the result was an improvement! This naive question raised some new prospects.

There is much more to do, and we explain some potential areas of work in the next section. It is not expected that these questions and problems are of equal interest or solvability!

Some of these matters discussed are speculative; it seems right to quote here from a letter of Alexander Grothendieck dated 14/06/83:

> Of course, no creative mathematician can afford not to "speculate", namely to do more or less daring guesswork as an indispensable source of inspiration. The trouble is that, in obedience to a stern tradition, almost nothing of

> this appears in writing, and preciously little even in oral communication. The point is that the disrepute of "speculation" or "dream" is such, that even as a strictly private (not to say secret!) activity, it has a tendency to vegetate – much like the desire and drive of love and sex, in too repressive an environment.

Any new idea has to be caught as it flashes across the mind, or it might vanish; talking about ideas can help to make them real, though it can also raise some funny looks from superior persons!

16.1 Problems and questions

There are a number of standard methods and results in algebraic topology to which the techniques of crossed complexes given here have not been applied, or applied only partially. So we leave these open for work to be done, and for you to decide how the uses in these areas of crossed complexes and related structures can advance the subjects of algebraic topology and homological algebra. We expect you to use texts and the internet for additional references and sources for further details, with the usual cautions about not relying totally on all that is there. Also you must do your own assessment of the possible value of these questions.

Problem 16.1.1. There has been surprisingly little general use in low-dimensional topology and geometric group theory of the HHSvKT for crossed modules, Theorem 2.3.1: this theorem is not even mentioned in [HAMS93], though some consequences are given. We mention again the important work of Papakyriakopoulos on relations between group theory and the Poincaré conjecture, [Pap63], which uses Whitehead's theorem on free crossed modules which, as shown in Theorem 5.4.8, is but one application of the 2-dimensional SvKT. Of course the Poincaré Conjecture has been resolved by different, and differential, rather than combinatorial or group theoretic, means. Recent uses of the 2-dimensional Seifert–van Kampen Theorem are by [KFM08], [FM09]. Perhaps even more surprising uses could be made of the triadic results in [BL87], [BL87a], relating to surgery problems, and borrowing methods from [Ell93]? See also [FM11]. □

Problem 16.1.2. Investigate applications of the enrichment of the category FTop over the monoidal closed category Crs in the spirit of the work on 2-groupoids in [KP02]. In fact, as an exercise, translate the work of the last paper into the language of crossed complexes and their internal homs. □

Problem 16.1.3. Investigate and apply Mayer–Vietoris type exact sequences for a pullback of a fibration of crossed complexes, analogous to that given for a pullback of a covering morphism of groupoids in [Bro06], Section 10.7. See also [HK81], [BHK83]. □

Problem 16.1.4. Can one use crossed complexes to give a finer form of Poincaré Duality? For an account of this duality, see for example Chapter 16 in [tD08]. This might require developing cup and cap products, which should be no problem, and also coefficients in an object with an analogue of a 'ring structure'. These could be the crossed differential algebras (i.e. monoid objects in the monoidal category Crs) considered in [BT97], and the braided regular crossed modules of [BG89a], further developed in [AU07]. See also the paper [Bro10b]. One would like to relate these ideas to older intuitions for Poincaré duality as explained in for example [ST80]. □

Problem 16.1.5. Another standard area in algebraic topology is *fixed point theory*, which includes the Lefschetz theory, involving homology, and also Nielsen theory, involving the fundamental group. Can these be combined? Perhaps one needs abstract notions for the Lefschetz number analogous to those found for the Euler characteristic, and with values in some ring generalising the integers? Relevant papers on this are perhaps [Hea05], [Pon09], [PS09]. Note that the last two papers use symmetric monoidal categories, and all use groupoid techniques. □

Problem 16.1.6. Are there possible results on the fundamental crossed complex of an orbit space of a filtered space analogous to those for the fundamental groupoid of an orbit space given in [Bro06], Chapter 11? Some related work is in [HT82]. But in Chapter 11 of [Bro06] a key result is on path lifting. Can one get some homotopy lifting using subdivisions of a square and the retraction arguments used in the proof of Proposition 14.2.8? □

Problem 16.1.7. Are there applications of crossed complexes to the nonabelian cohomology of fibre spaces? Could the well developed acyclic model theory and fibre spaces of [GM57] be suitably modified and used? The spectral sequence of filtered crossed complexes has been developed by Baues in [Bau89], but surely more work needs to be done. Note also that while the theory of simplicial fibre bundles is well developed, the cubical theory has problems because the categorical product of cubical sets has poor homotopical properties. This might be solved by using cubical sets with connections: the paper [Mal09] on the geometric realisation of such structures is surely relevant, as is [FMP11]. □

Problem 16.1.8. The category Gpds of groupoids does not satisfy some properties analogous to those of the category of groups, for example is not semi-abelian in the sense of [JMT02]. However it seems that each fibre of the functor $\mathsf{Ob}\colon \mathsf{Gpds} \to \mathsf{Set}$ is semi-abelian. Is it reasonable to investigate for purposes of homological algebra the general situation of fibrations of categories such that each fibre is semi-abelian, and can such a generalised theory be helpfully applied to crossed complexes? □

Problem 16.1.9. Can one apply to the cubical collapses of Section 11.3.i the methods of finite topological spaces as applied to collapses of simplicial complexes in [BM09]? □

Problem 16.1.10. Is there a nonabelian *homological perturbation theory* for constructing nonabelian twisted tensor products from fibrations? As a start in the literature, see

[BL91]. Or for constructing small free crossed resolutions of groups? References for the standard theory, and the important relation to twisted tensor products, may be found by a web search. □

Problem 16.1.11. The standard theory of chain complexes makes much use of double chain complexes. Double crossed complexes have been defined in [Ton94] but presumably there is much more to be done here. □

Problem 16.1.12. The theory of equivariant crossed complexes has already been developed in [BGPT97], [BGPT01]. However notions such as fibrations of crossed complexes have not been applied in that area. □

Problem 16.1.13. Can one make progress with nonabelian cohomology operations? The tensor product of crossed complexes is symmetric, as proved in Section 15.4. So if K is a simplicial set, then we can consider the noncommutativity of the diagonal map $\Delta\colon \pi|K| \to \pi|K| \otimes |K|$. If T is the twisting map $A \otimes B \to B \otimes A$, then there is a natural homotopy $T\Delta \simeq \Delta$, by the usual acyclic models argument. This look like the beginnings of a theory of nonabelian Steenrod cohomology operations. Does such a theory exist and does it hold any surprises? By contrast, [Bau89] gives an obstruction to the existence of a Pontrjagin square with local coefficients. □

Problem 16.1.14. One use of chain complexes is in defining Kolmogorov–Steenrod homology. One takes the usual net of polyhedra defined as the nerves of open covers of a space X, with maps between them induced by choices of refinements. The result is a homotopy coherent diagram of polyhedra. This is also related to Čech homology theory. It is shown in [Cor87] that a strong homology theory results by taking the chain complexes of this net, and forming the chain complex which is the homotopy inverse limit. What sort of strong homology theory results from using the fundamental crossed complexes of the nerves instead of the chain complexes? Is there a kind of 'strong fundamental groupoid', and could this be related to defining universal covers of spaces which are not locally 'nice'? □

Problem 16.1.15. There are a number of areas of algebraic topology where chain complexes with a group of operators are used, for example [Coh73], [RW90]. Is it helpful to reformulate this work in terms of crossed complexes? Note that Section 17 of [Whi50b] is given in terms of crossed complexes, but the exposition there is sparse; we have earlier related this work to that of Baues in [Bau89], p. 357. A related work on simple homotopy theory is [Bro92], which is also related to generalisations of Tietze equivalences of presentations. Standard expositions of simple homotopy theory, for example [Coh73], are in terms of chain complexes with operators. It may be worth going back to the paper which introduced many of these ideas, namely [Whi41b]. Note that simple homotopy theory is applied to manifolds using filtrations defined by a Morse function in [Maz65]. □

Problem 16.1.16. Another example for the last problem of replacing chain complexes by crossed complexes is the work of Dyer and Vasquez in [DV73] on CW-models for one-relator groups. Can that work be helpfully reworked in terms of crossed complexes and the techniques of Chapter 10? The paper [Lod00] gives some problems on identities among relations. □

Problem 16.1.17. Can the use of crossed complexes in Morse theory explained by Sharko in [Sha93] be further developed? He writes at the beginning of Chapter VII:

> The need to make use of homotopy systems [i.e. free crossed complexes] in order to study Morse functions on non-simply connected closed manifolds or on manifolds with one boundary component arises from the failure of the chain complexes constructed from the Morse functions and gradient-like vector fields to capture completely the geometric aspects of the problem. This relates to application of the Whitney lemma to the reduction of the number of points of intersection of manifolds of complementary dimensions.

Problem 16.1.18. Baues and Tonks in [BT97] use crossed complexes to study the cobar construction. But the original work on the cobar construction in [AH56] was cubical. Can one do better by using many base points instead of just loop spaces, and also using ω-groupoids instead of crossed complexes? □

Problem 16.1.19. Find applications of these nonabelian constructions to configuration space theory and mapping space theory, particularly the theory of spaces of rational maps. More generally, one can look at areas where the standard tools are simplicial abelian groups, classifying spaces, and some notion of freeness. □

Problem 16.1.20. A further aim is to use these methods in the theory of stacks and gerbes, and more generally in differential topology and geometry. The ideas of Section 12.5.i are hopefully a start on this. The paper [FMP11] uses directly methods of our ω-groupoids, and for similar reasons to ours, but in the context of smooth manifolds rather than filtered spaces. □

Problem 16.1.21. Investigate the relation between the cocycle approach to Postnikov invariants and that given using triple cohomology and crossed complexes in [BFGM05]. □

Problem 16.1.22. One starting intuition for the proof of the HHSvKT was the wish to algebraicise the proof of the cellular approximation theorem due to Frank Adams, and given in [Bro68], [Bro06]. Now a subtle proof of an excision connectivity theorem of Blakers and Massey is given in [tD08], Section 6.9. Can one use methods of crossed squares or cat^n-groups to algebraicise this proof? □

Problem 16.1.23. It would be good to have another proof of the main result of [BB93], using cubical ω-groupoids. Perhaps one needs also some of the methods of [tD08], Section 6.9? □

Problem 16.1.24. There are many problems associated with generalisation of the HHSvKT to n-cubes of spaces as given in [BL87], [BL87a]. For a survey, and references to related literature, see [Bro92]. Recent works in this area are [EM10], [MW10]. It is not clear what should be the appropriate generalisation to a many base point approach of the work on the fundamental cat^n-group of an n-cube of spaces explained in [BL87], [Gil87]. Note the idea of a fundamental double groupoid of a map of spaces in [BJ04]. Can this be generalised to n-cubes of spaces? Grothendieck remarked in 1985 to Brown that the idea that (strict) n-fold groupoids model homotopy n-types was 'absolutely beautiful!'. Some relation of cat^n-groups to other models is developed in [Pao09]. □

Problem 16.1.25. The term ∞-groupoid has been used for the simplicial singular complex $S^{\Delta}X$ of a space X and this has also been written ΠX. See for example [Ber02], [Lur09], [JT07]. However the axiomatic properties of the *cubical* singular complex $S^{\Box}X$, with its multiple compositions which we use greatly in this book, have not been much investigated. We mention [Ste06] as an approach to using Kan fillers in a categorical situation. □

Problem 16.1.26. The area of homological algebra has been invigorated by the notion of triangulated category and related areas, see for example [Nee01], [Kün07]. These are related to chain complexes, also called differential graded objects. However the work of Fröhlich and of Lue, for which see references in [Lue71], shows the relevance of general notions of crossed modules. Crossed modules and triangulated categories are also used in [MTW10]. Again work of Tabuada [Tab09], [Tab10] relates Postnikov invariants and monoidal closed categories. But this is done for dg-objects without the crossed module environment.

Problem 16.1.27. One intention of the work of Mosa, [Mos87], was to start on working out the homological algebra of algebroids (rings with several objects) by defining crossed resolutions of algebroids and obtaining a monoidal closed structure on crossed complexes of algebroids. However even the conjectured equivalence between crossed complexes of algebroids and higher dimensional cubical algebroids is unsolved. The difficulty is shown by the complexity of the arguments in [AABS02] compared with those of Chapter 13 of this book. □

Problem 16.1.28. A programme set by Grothendieck in 'Pursuing Stacks' is related to the previous problem. We quoted on p. xiv his aim to understand noncommutative cohomology of topoi. Earlier in the same letter he writes:

> For the last three weeks I haven't gone on writing the notes, as what was going to follow next is presumably so smooth that I went out for some scratchwork on getting an idea about things more obscure still, particularly about understanding the basic structure of '(possibly non-commutative) "derived categories", and the internal homotopy-flavoured properties of the "basic modelizer" (Cat), namely of functors between "small" categories,

> modelled largely on work done long time ago about étale cohomology properties of maps of schemes. I am not quite through yet but hope to resume work on the notes next week.

For work of Grothendieck on 'Modelizers' and 'Derivateurs', see [Gro89], [MaltDer]. □

Problem 16.1.29. The last problem is possibly related to the problem of relating the methods of this book to those of the modern theory of sheaves, as discussed in [Ive86], with applications to generalised Poincaré duality, known as Verdier duality. A related area is that of stratified spaces, on which a recent paper using higher order categories is [Woo10]. Stratifications are referred to in [Gro97], Section 5, while in 1983 Grothendieck wrote to Brown, see [GroPS2]:

> It seems to me, in any case, that this $\varinjlim$-operation ["higher order van Kampen theorem"] in the context of homotopy types is of a very fundamental character, with wide range of theoretical applications. To give just one example, relying on the existence of such a formalism, it is possible to give a very simple explicit algebraic description of the full homotopy types of the Mumford–Deligne compactifications of the modular topoi for complex curves of given genus g, say, with ν "marked" points, in terms essentially of such a (finite) direct limit of $K(\pi, 1)$-spaces, where π ranges over certain "elementary" Teichmüller groups (those, roughly, corresponding to modular dimension $\leqslant 2$), and to give analogous descriptions, too, of all those subtopoi of the previous one, deducible from its canonical "stratification" at infinity by taking unions of strata. In fact, such descriptions should apply to any kind of "stratified" space or topos, as it can be expressed (in an essentially canonical way, which apparently was never made explicit yet in this literature) as a (usually finite) direct limit of simpler spaces, namely the "strata", and "tubes" around strata, and "junctions" of tubes, etc. Such a formalism was alluded to in one of my letters to Larry, in connection with so-called "tame topology" – a framework which has yet to be worked out – and I was more or less compelled lately to work it out heuristically in some detail, in order to get precise clues for working out a description of the fundamental groupoids of Mumford–Deligne–Teichmüller modular topoi (namely, essentially, of the standard Teichmüller groups), suitable for the arithmetic aspects I had in mind (namely, for a grasp of the action of the Galois group $\mathrm{Gal}_{\bar{Q}/Q}$ on the profinite completion).

However the methods of this book have not yet been applied in this area, and much work on 'tame topology' has been done since 1983. Relations between the 'crossed' techniques of this book and profinite theory are developed in the monograph [Por12]. □

Problem 16.1.30. A work on monoidal categories, Hopf algebras, species and related areas, and which strongly uses the Eilenberg–Zilber Theorem for chain complexes, is [AM10]. There are possibilities of relating their work to that done here, or bringing in crossed complexes into the areas studied in that book. □

Problem 16.1.31. Can this area of crossed complexes be helpfully related to that of complexes of groups, which generalises graphs of groups, as initiated by Haefliger in [Hae92]?

Problem 16.1.32. There is an extensive theory of quantum groups and of quantum groupoids. Can this be extended to 'quantum crossed complexes' using the methods of [Chi11], and related papers referenced there? □

Other problems in crossed complexes and related areas are given in [Bro90].

Bibliography

The numbers at the end of each item refer to the pages on which the respective work is cited.

[AHS06] Adámek, J., Herrlich, H., and Strecker, G. E., Abstract and concrete categories: the joy of cats. *Repr. Theory Appl. Categ.* (17) (2006) 1–507. Reprint of the 1990 original (Wiley, New York).

[Ada56] Adams, J. F., Four applications of the self-obstruction invariants. *J. London Math. Soc.* **31** (1956) 148–159.

[Ada72] Adams, J. F., *Algebraic topology—a student's guide*. London Math. Soc. Lecture Note Ser. 4, Cambridge University Press, London (1972).

[Ada78] Adams, J. F., *Infinite loop spaces*. Ann. Math. Stud. 90, Princeton University Press, Princeton, N.J. (1978).

[AH56] Adams, J. F., and Hilton, P. J., On the chain algebra of a loop space. *Comment. Math. Helv.* **30** (1956) 305–330.

[AM10] Aguiar, M., and Mahajan, S., *Monoidal functors, species and Hopf algebras*. CRM Monogr. Ser. 29, Amer. Math. Soc., Providence, RI (2010).

[AA89] Al-Agl, F., *Aspects of multiple categories*. Ph.D. thesis, University of Wales, Bangor (1989).

[AABS02] Al-Agl, F. A., Brown, R., and Steiner, R., Multiple categories: the equivalence of a globular and a cubical approach. *Adv. Math.* **170** (1) (2002) 71–118.

[AF61] Aleksandrov, P. S., and Finikov, S. P., Eduard Čech: Obituary. *Uspehi Mat. Nauk* **16** (1 (97)) (1961) 119–126 (1 plate).

[AW00] Alp, M., and Wensley, C. D., Enumeration of cat^1-groups of low order. *Internat. J. Algebra Comput.* **10** (4) (2000) 407–424.

[AW10] Alp, M., and Wensley, C. D., Automorphisms and homotopies of groupoids and crossed modules. *Appl. Cat. Struct.* **18** (5) (2010) 473–504.

[And78] Anderson, D. W., Fibrations and geometric realizations. *Bull. Amer. Math. Soc.* **84** (5) (1978) 765–788.

[And57] Ando, H., A note on Eilenberg-MacLane invariant. *Tôhoku Math. J.* (2) **9** (1957) 96–104.

[AN09] Andruskiewitsch, N., and Natale, S., The structure of double groupoids. *J. Pure Appl. Algebra* **213** (6) (2009) 1031–1045.

[Ant00] Antolini, R., Cubical structures, homotopy theory. *Ann. Mat. Pura Appl.* (4) **178** (2000) 317–324.

[AM11] Ara, D., and Métayer, F., The Brown-Golasiński model structure on ∞-groupoids revisited. *Homology, Homotopy, Appl.* **13** (2011) 121–142.

[Art72] Artzy, R., Kurt Reidemeister, (13.10.1893- 8.7.1971). *Jahresberichte der Deutschen Mathematiker-Vereinigung* **74** (1972) 96–104.

[AU06] Arvasi, Z., and Ulualan, E., On algebraic models for homotopy 3-types. *J. Homotopy Relat. Struct.* **1** (1) (2006) 1–27.

[AU07] Arvasi, Z., and Ulualan, E., 3-types of simplicial groups and braided regular crossed modules. *Homology, Homotopy Appl.* **9** (1) (2007) 139–161.

[Ash88] Ashley, N., Simplicial T-complexes and crossed complexes: a nonabelian version of a theorem of Dold and Kan. With a preface by R. Brown, *Dissertationes Math.* (*Rozprawy Mat.*) **265** (1988) 1–61.
http://ehres.pagesperso-orange.fr/Cahiers/AshleyEM32.pdf

[BS90] Babaev, A. A., and Soloviev, S. V., On conditions of full coherence in biclosed categories: a new application of proof theory. In *COLOG*-88 (Tallinn, 1988), Lecture Notes in Comput. Sci. 417, Springer-Verlag, Berlin (1990), 3–8.

[BL04] Baez, J. C., and Lauda, A. D., Higher-dimensional algebra. V. 2-groups. *Theory Appl. Categ.* **12** (2004) 423–491.

[BS09] Baez, J. C., and Stevenson, D., The classifying space of a topological 2-group. In *Algebraic topology*, Abel Symp. 4, Springer-Verlag, Berlin (2009), 1–31.

[BM09] Barmak, J. A., and Minian, E. G., Strong homotopy types, nerves and collapses. *Discrete Comput. Geom.*, to appear. DOI10.1007/s00454-011-9357-5.

[BL91] Barnes, D. W., and Lambe, L. A., A fixed point approach to homological perturbation theory. *Proc. Amer. Math. Soc.* **112** (3) (1991) 881–892.

[Bar79] Barr, M., $*$-*autonomous categories*. With an appendix by Po Hsiang Chu, Lecture Notes in Math. 752, Springer-Verlag, Berlin (1979).

[Bar02] Barr, M., *Acyclic models*. CRM Monograph Series 17, Amer. Math. Soc., Providence, RI (2002).

[BW56] Barratt, M. G., and Whitehead, J. H. C., The first nonvanishing group of an $(n+1)$-ad. *Proc. London Math. Soc.* (3) **6** (1956) 417–439.

[BE69] Bastiani, A., and Ehresmann, C., Catégories de foncteurs structurés. *Cahiers Topologie Géom. Différentielle* **11** (1969) 329–384.

[BE72] Bastiani, A., and Ehresmann, C., Categories of sketched structures. *Cahiers Topologie Géom. Différentielle* **13** (1972) 105–214.

[Bau89] Baues, H. J., *Algebraic homotopy*, Cambridge Studies in Advanced Mathematics 15, Cambridge University Press, Cambridge (1989).

[Bau91] Baues, H. J., *Combinatorial homotopy and* 4-*dimensional complexes*. With a preface by Ronald Brown, de Gruyter Expositions in Mathematics 2. Walter de Gruyter & Co., Berlin (1991).

[BB93] Baues, H. J., and Brown, R., On relative homotopy groups of the product filtration, the James construction, and a formula of Hopf. *J. Pure Appl. Algebra* **89** (1-2) (1993) 49–61.

[BC90] Baues, H. J., and Conduché, D., The central series for Peiffer commutators in groups with operators. *J. Algebra* **133** (1) (1990) 1–34.

[BC92] Baues, H. J., and Conduché, D., On the tensor algebra of a nonabelian group and applications. *K-Theory* **5** (6) (1991/92) 531–554.

[BT97] Baues, H.-J., and Tonks, A., On the twisted cobar construction. *Math. Proc. Cambridge Philos. Soc.* **121** (2) (1997) 229–245.

[Bén63] Bénabou, J., Catégories avec multiplication. *C. R. Acad. Sci. Paris* **256** (1963) 1887–1890.

[Bén64] Bénabou, J., Algèbre élémentaire dans les catégories avec multiplication. *C. R. Acad. Sci. Paris* **258** (1964) 771–774.

[Bén65] Bénabou, J., Catégories relatives. *C. R. Acad. Sci. Paris* **260** (1965) 3824–3827.

[Bén67] Bénabou, J., Introduction to bicategories. In *Reports of the Midwest Category Seminar*, Springer-Verlag, Berlin (1967), 1–77.

[Ber02] Berger, C., A cellular nerve for higher categories. *Adv. Math.* **169** (1) (2002) 118–175.

[BL70] Birkhoff, G., and Lipson, J. D., Heterogeneous algebras. *J. Combinatorial Theory* **8** (1970) 115–133.

[Bjö92] Björner, A., The homology and shellability of matroids and geometric lattices. In Matroid applications. In *Encyclopedia Math. Appl.* 40, Cambridge University Press, Cambridge (1992), 226–283.

[Bla48] Blakers, A., Some relations between homology and homotopy groups. *Ann. of Math.* (2) **49** (1948) 428–461.

[BM49] Blakers, A. L., and Massey, W. S., The homotopy groups of a triad. *Proc. Nat. Acad. Sci. U. S. A.* **35** (1949) 322–328.

[BJT10] Blanc, D., Johnson, M. W., and Turner, J. M., Higher homotopy operations and cohomology. *J. K-Theory* **5** (1) (2010) 167–200.

[Bog94] Bogley, W. A., Unions of Cockcroft two-complexes. *Proc. Edinburgh Math. Soc.* (2) **37** (2) (1994) 317–324.

[BG00] Bogley, W. A., and Gilbert, N. D., The homology of Peiffer products of groups. *New York J. Math.* **6** (2000) 55–71 (electronic).

[BG92] Bogley, W. A., and Gutiérrez, M. A., Mayer-Vietoris sequences in homotopy of 2-complexes and in homology of groups. *J. Pure Appl. Algebra* **77** (1) (1992) 39–65.

[BO93] Book, R. V., and Otto, F., *String-rewriting systems*. Texts and Monographs in Computer Science, Springer-Verlag, New York (1993).

[BB78] Booth, P. I., and Brown, R., On the application of fibred mapping spaces to exponential laws for bundles, ex-spaces and other categories of maps. *General Topology and Appl.* **8** (2) (1978) 165–179.

[BT80] Booth, P. I., and Tillotson, J., Monoidal closed categories and convenient categories of topological spaces. *Pacific J. Math.* **88** (1980) 33–53.

[Bor94] Borceux, F., *Handbook of categorical algebra. 1. Basic category theory*. Encyclopedia of Mathematics and its Applications 50, Cambridge University Press, Cambridge (1994).

[BB04] Borceux, F., and Bourn, D., *Mal'cev, protomodular, homological and semi-abelian categories*. Math. Appl. 566, Kluwer Academic Publishers, Dordrecht (2004).

[BJ01] Borceux, F., and Janelidze, G., *Galois theories*. Cambridge Stud. Adv. Math. 72, Cambridge University Press, Cambridge (2001).

[Bou70] Bourbaki, N., *Éléments de mathématique. Théorie des ensembles*. Hermann, Paris (1970).

[Bou87] Bourn, D., The shift functor and the comprehensive factorization for internal groupoids. *Cahiers Topologie Géom. Différentielle Catég.* **28** (3) (1987) 197–226.

[Bou07] Bourn, D., Moore normalization and Dold-Kan theorem for semi-abelian categories. In *Categories in algebra, geometry and mathematical physics*, Contemp. Math. 431, Amer. Math. Soc., Providence, RI (2007), 105–124.

[Bra26] Brandt, H., Über eine Verallgemeinerung des Gruppenbegriffes. *Math. Ann.* **96** (4) (1926) 360–366.

[Bre94] Breen, L., On the classification of 2-gerbes and 2-stacks. *Astérisque* **225** (1994).

[Bro59] Brown, E. H., Jr., Twisted tensor products. I. *Ann. of Math.* (2) **69** (1959) 223–246.

[Bro94] Brown, K. S., *Cohomology of groups*. Grad. Texts in Math. 87, Springer-Verlag, New York (1994). Corrected reprint of the 1982 original.

[Bro62] Brown, R., *Some problems in algebraic topology: function spaces and FD-complexes*. Ph.D. thesis, University of Oxford (1962).

[Bro63] Brown, R., Ten topologies for $X \times Y$. *Quart. J. Math. Oxford Ser.* (2) **14** (1963) 303–319.

[Bro64a] Brown, R., Cohomology with chains as coefficients. *Proc. London Math. Soc.* (3) **14** (1964) 545–565.

[Bro64b] Brown, R., Function spaces and product topologies. *Quart. J. Math. Oxford Ser.* (2) **15** (1964) 238–250.

[Bro64c] Brown, R., On Künneth suspensions. *Proc. Cambridge Philos. Soc.* **60** (1964) 713–720.

[Bro65a] Brown, R., On a method of P. Olum. *J. London Math. Soc.* **40** (1965) 303–304.

[Bro65b] Brown, R., The twisted Eilenberg-Zilber theorem. In *Simposio di Topologia* (Messina, 1964), Edizioni Oderisi, Gubbio (1965), 33–37.

[Bro66] Brown, R., Two examples in homotopy theory. *Proc. Cambridge Philos. Soc.* **62** (1966) 575–576.

[Bro67] Brown, R., Groupoids and van Kampen's theorem. *Proc. London Math. Soc.* (3) **17** (1967) 385–401.

[Bro68] Brown, R., *Elements of modern topology*. McGraw-Hill Book Co., New York (1968).

[Bro70] Brown, R., Fibrations of groupoids. *J. Algebra* **15** (1970) 103–132.

[Bro80] Brown, R., On the second relative homotopy group of an adjunction space: an exposition of a theorem of J. H. C. Whitehead. *J. London Math. Soc.* (2) **22** (1) (1980) 146–152.

[Bro82] Brown, R., Higher dimensional group theory. In *Low-dimensional topology* (Bangor, 1979), London Math. Soc. Lecture Note Ser. 48, Cambridge University Press, Cambridge (1982), 215–238.

[Bro83] Brown, R., An introduction to simplicial T-complexes. *Esquisses Math.* **32** (1983) 1–27. http://ehres.pagesperso-orange.fr/Cahiers/brownEM32.pdf

[Bro84a] Brown, R., Coproducts of crossed P-modules: applications to second homotopy groups and to the homology of groups. *Topology* **23** (3) (1984) 337–345.

[Bro84b] Brown, R., Nonabelian cohomology and the homotopy classification of maps. In *Algebraic homotopy and local algebra* (Luminy, 1982), *Astérisque* **113** (1984), Soc. Math. France, Paris, 167–172.

[Bro87] Brown, R., From groups to groupoids: a brief survey. *Bull. London Math. Soc.* **19** (2) (1987) 113–134.

[Bro89] Brown, R., Triadic Van Kampen theorems and Hurewicz theorems. In *Algebraic topology* (Evanston, IL, 1988), Contemp. Math. 96, Amer. Math. Soc., Providence, RI (1989), 39–57.

[Bro90] Brown, R., Some problems in nonabelian homotopical and homological algebra. In *Homotopy theory and related topics* (Kinosaki, 1988), Lecture Notes in Math. 1418, Springer-Verlag, Berlin (1990), 105–129.

[Bro92] Brown, R., Computing homotopy types using crossed n-cubes of groups. In *Adams Memorial Symposium on Algebraic Topology, 1* (Manchester, 1990), London Math. Soc. Lecture Note Ser. 175, Cambridge University Press, Cambridge (1992), 187–210.

[Bro94] Brown, R., Higher order symmetry of graphs. *Irish Math. Soc. Bull.* **32** (1994) 46–59.

[Bro96] Brown, R., Higher dimensional group theory. (1996) http://www.bangor.ac.uk/r.brown/hdaweb2.htm.

[Bro99] Brown, R., Groupoids and crossed objects in algebraic topology. *Homology Homotopy Appl.* **1** (1999) 1–78.

[Bro06] Brown, R., *Topology and groupoids*. Printed by Booksurge LLC, Charleston, S. Carolina, third edition (2006).

[Bro07] Brown, R., Three themes in the work of Charles Ehresmann: Local-to-global; groupoids; higher dimensions. In *7th Conference on the geometry and topology of manifolds: The mathematical legacy of Charles Ehresmann*, Bedlewo, Poland, 8.05.2005–15.05.2005, Banach Centre Publications 76, Institute of Mathematics, Polish Academy of Sciences, Warsaw (2007), 51–63.

[Bro08a] Brown, R., Exact sequences of fibrations of crossed complexes, homotopy classification of maps, and nonabelian extensions of groups. *J. Homotopy Relat. Struct.* **3** (1) (2008) 331–342.

[Bro08b] Brown, R., A new higher homotopy groupoid: the fundamental globular ω-groupoid of a filtered space. *Homology, Homotopy Appl.* **10** (1) (2008) 327–343.

[Bro09a] Brown, R., 'Double modules', double categories and groupoids, and a new homotopy double groupoid. arXiv:0903.2627 [math.CT] (2009) 1–8.

[Bro09b] Brown, R., Moore hyperrectangles on a space form a strict cubical omega-category. arXiv:0909.2212v4 [math.CT] (2009) 1–7.

[Bro10a] Brown, R., On the homotopy 2-type of a free loop space. arXiv:1003.5617 [math.AT] (2010) 1–5.

[Bro10b] Brown, R., Possible connections between whiskered categories and groupoids, Leibniz algebras, automorphism structures and local-to-global questions. *J. Homotopy Relat. Struct.* **5** (1) (2010) 305–318.

[Bro11] Brown, R., Covering morphisms of groupoids, derived modules and a 1-dimensional Relative Hurewicz Theorem. arXiv:1012.2824 [math.AT] (2011) 1–17.

[BE88] Brown, R., and Ellis, G. J., Hopf formulae for the higher homology of a group. *Bull. London Math. Soc.* **20** (2) (1988) 124–128.

[BG89a] Brown, R., and Gilbert, N. D., Algebraic models of 3-types and automorphism structures for crossed modules. *Proc. London Math. Soc.* (3) **59** (1) (1989) 51–73.

[BG89b] Brown, R., and Golasiński, M., A model structure for the homotopy theory of crossed complexes. *Cahiers Topologie Géom. Différentielle Catég.* **30** (1) (1989) 61–82.

[BGPT97] Brown, R., Golasiński, M., Porter, T. and Tonks, A. Spaces of maps into classifying spaces for equivariant crossed complexes. *Indag. Math. (N.S.)* **8** (2) (1997) 157–172.

[BGPT01] Brown, R., Golasiński, M., Porter, T. and Tonks, A. Spaces of maps into classifying spaces for equivariant crossed complexes. II. The general topological group case. *K-Theory* **23** (2) (2001) 129–155.

[BHKP02] Brown, R., Hardie, K. A., Kamps, K. H., and Porter, T., A homotopy double groupoid of a Hausdorff space. *Theory Appl. Categ.* **10** (2002) 71–93 (electronic).

[BH70] Brown, R., and Heath, P. R., Coglueing homotopy equivalences. *Math. Z.* **113** (1970) 313–325.

[BH87] Brown, R., and Heath, P. R., Lifting amalgamated sums and other colimits of groups and topological groups. *Math. Proc. Cambridge Philos. Soc.* **102** (2) (1987) 273–280.

[BHK83] Brown, R., Heath, P. R., and Kamps, K. H., Groupoids and the Mayer-Vietoris sequence. *J. Pure Appl. Algebra* **30** (2) (1983) 109–129.

[BH77] Brown, R., and Higgins, P. J., Sur les complexes croisés, ω-groupoïdes, et T-complexes. *C. R. Acad. Sci. Paris Sér. A-B* **285** (16) (1977) A997–A999.

[BH78a] Brown, R., and Higgins, P. J., On the connection between the second relative homotopy groups of some related spaces. *Proc. London Math. Soc.* (3) **36** (2) (1978) 193–212.

[BH78b] Brown, R., and Higgins, P. J., Sur les complexes croisés d'homotopie associés à quelques espaces filtrés. *C. R. Acad. Sci. Paris Sér. A-B* **286** (2) (1978) A91–A93.

[BH81] Brown, R., and Higgins, P. J., On the algebra of cubes. *J. Pure Appl. Algebra* **21** (3) (1981) 233–260.

[BH81a] Brown, R., and Higgins, P. J., Colimit theorems for relative homotopy groups. *J. Pure Appl. Algebra* **22** (1) (1981) 11–41.

[BH81b] Brown, R., and Higgins, P. J., The equivalence of ∞-groupoids and crossed complexes. *Cahiers Topologie Géom. Différentielle* **22** (4) (1981) 371–386.

[BH81c] Brown, R., and Higgins, P. J., The equivalence of ω-groupoids and cubical T-complexes. *Cahiers Topologie Géom. Différentielle* **22** (4) (1981) 349–370.

[BH82] Brown, R., and Higgins, P. J., Crossed complexes and nonabelian extensions. In *Int. Conf. on Category theory* (Gummersbach, 1981), Lecture Notes in Math. 962, Springer-Verlag, Berlin (1982), 39–50.

[BH87] Brown, R., and Higgins, P. J., Tensor products and homotopies for ω-groupoids and crossed complexes. *J. Pure Appl. Algebra* **47** (1) (1987) 1–33.

[BH89] Brown, R., and Higgins, P. J., The classifying space of a crossed complex. UWB Math. Preprint **89.06** (1989) 30pp.

[BH90] Brown, R., and Higgins, P. J., Crossed complexes and chain complexes with operators. *Math. Proc. Cambridge Philos. Soc.* **107** (1) (1990) 33–57.

[BH91] Brown, R., and Higgins, P. J., The classifying space of a crossed complex. *Math. Proc. Cambridge Philos. Soc.* **110** (1) (1991) 95–120.

[BH03] Brown, R., and Higgins, P. J., Cubical abelian groups with connections are equivalent to chain complexes. *Homology Homotopy Appl.* **5** (1) (2003) 49–52 (electronic).

[BH82] Brown, R., and Huebschmann, J., Identities among relations. In *Low-dimensional topology* (Bangor, 1979), London Math. Soc. Lecture Note Ser. 48, Cambridge University Press, Cambridge (1982), 153–202.

[Bİ03a] Brown, R., and İcen, İ., Homotopies and automorphisms of crossed modules of groupoids. *Appl. Categ. Structures* **11** (2) (2003) 185–206.

[Bİ03b] Brown, R., and İcen, İ., Towards a 2-dimensional notion of holonomy. *Adv. Math.* **178** (1) (2003) 141–175.

[BJ99] Brown, R., and Janelidze, G., Galois theory of second order covering maps of simplicial sets. *J. Pure Appl. Algebra* **135** (1) (1999) 23–31.

[BJ04] Brown, R., and Janelidze, G., Galois theory and a new homotopy double groupoid of a map of spaces. *App. Cat. Struct.* **12** (2004) 63–80.

[BKP05] Brown, R., Kamps, K. H., and Porter, T., A homotopy double groupoid of a Hausdorff space. II. A van Kampen theorem. *Theory Appl. Categ.* **14** (9) (2005) 200–220 (electronic).

[BL87] Brown, R., and Loday, J.-L., Van Kampen theorems for diagrams of spaces. *Topology* **26** (3) (1987) 311–335. With an appendix by M. Zisman.

[BL87a] Brown, R., and Loday, J.-L., Homotopical excision, and Hurewicz theorems for n-cubes of spaces. *Proc. London Math. Soc.* (3) **54** (1) (1987) 176–192.

[BM92] Brown, R., and Mackenzie, K. C. H., Determination of a double Lie groupoid by its core diagram. *J. Pure Appl. Algebra* **80** (3) (1992) 237–272.

[BMPW02] Brown, R., Moore, E. J., Porter, T., and Wensley, C. D., Crossed complexes, and free crossed resolutions for amalgamated sums and HNN-extensions of groups. Dedicated to Professor Hvedri Inassaridze on the occasion of his 70th birthday. *Georgian Math. J.* **9** (4) (2002) 623–644.

[BMSW08] Brown, R., Morris, I., Shrimpton, J., and Wensley, C. D., Graphs of morphisms of graphs. *Electron. J. Combin.* **15** (1) (2008) Article 1, 28.

[BM99] Brown, R., and Mosa, G. H., Double categories, 2-categories, thin structures and connections. *Theory Appl. Categ.* **5** (7) (1999) 163–175 (electronic).

[BM94] Brown, R., and Mucuk, O., Covering groups of nonconnected topological groups revisited. *Math. Proc. Cambridge Philos. Soc.* **115** (1) (1994) 97–110.

[BN79] Brown, R., and Nickolas, P., Exponential laws for topological categories, groupoids and groups, and mapping spaces of colimits. *Cahiers Topologie Géom. Différentielle* **20** (2) (1979) 179–198.

[BP96] Brown, R., and Porter, T., On the Schreier theory of non-abelian extensions: generalisations and computations. *Proc. Roy. Irish Acad. Sect. A* **96** (2) (1996) 213–227.

[BP03] Brown, R., and Porter, T., Category theory and higher dimensional algebra: potential descriptive tools in neuroscience. In *Proceedings of the International Conference on Theoretical Neurobiology* Delhi, February 2003, Volume 1 (2003), 80–92.

[BP06] Brown, R., and Porter, T., Category theory: an abstract setting for analogy and comparison. In *What is Category Theory?* Advanced Studies in Mathematics and Logic, Polimetrica Publisher, Monza (2006) 257–274.

[BRS84] Brown, R., and Razak Salleh, A., A van Kampen theorem for unions of nonconnected spaces. *Arch. Math.* (*Basel*) **42** (1) (1984) 85–88.

[BRS99] Brown, R., and Razak Salleh, A., Free crossed resolutions of groups and presentations of modules of identities among relations. *LMS J. Comput. Math.* **2** (1999) 28–61 (electronic).

[BS07] Brown, R., and Sivera, R., Normalisation for the fundamental crossed complex of a simplicial set. *J. Homotopy and Related Structures* (*Special issue devoted to the memory of Saunders Mac Lane*(**2** (2) (2007) 49–79.

[BS09] Brown, R., and Sivera, R., Algebraic colimit calculations in homotopy theory using fibred and cofibred categories. *Theory App. Cat.* **22** (2009) 221–251.

[BS76a] Brown, R., and Spencer, C. B., Double groupoids and crossed modules. *Cahiers Topologie Géom. Différentielle* **17** (4) (1976) 343–362.

[BS76b] Brown, R., and Spencer, C. B., G-groupoids, crossed modules and the fundamental groupoid of a topological group. *Nederl. Akad. Wetensch. Proc. Ser. A* **79** = *Indag. Math.* **38** (4) (1976) 296–302.

[BS10] Brown, R., and Street, R., Covering morphisms of crossed complexes and of cubical omega-groupoids are closed under tensor product. *Cahiers Topologie Géom. Différentielle*, to appear; arXiv:1009.5609v2 [math.AT] (2010) 1–15.

[BW95] Brown, R., and Wensley, C. D., On finite induced crossed modules, and the homotopy 2-type of mapping cones. *Theory Appl. Categ.* **1** (3) (1995) 54–70 (electronic).

[BW96] Brown, R., and Wensley, C. D., Computing crossed modules induced by an inclusion of a normal subgroup, with applications to homotopy 2-types. *Theory Appl. Categ.* **2** (1) (1996) 3–16 (electronic).

[BW03] Brown, R., and Wensley, C. D., Computation and homotopical applications of induced crossed modules. *J. Symbolic Comput.* **35** (1) (2003) 59–72.

[Bro92] Brown, R. A., Generalized group presentation and formal deformations of CW complexes. *Trans. Amer. Math. Soc.* **334** (2) (1992) 519–549.

[BP02] Buchstaber, V. M., and Panov, T. E., *Torus actions and their applications in topology and combinatorics*. University Lecture Series 24, Amer. Math. Soc., Providence, RI (2002).

[BFGM05] Bullejos, M., Faro, E., and García-Muñoz, M. A., Postnikov invariants of crossed complexes. *J. Algebra* **285** (1) (2005) 238–291.

[BN00] Bunge, M., and Niefield, S., Exponentiability and single universes. *J. Pure Appl. Algebra* **148** (3) (2000) 217–250.

[CC91] Carrasco, P., and Cegarra, A. M., Group-theoretic algebraic models for homotopy types. *J. Pure Appl. Algebra* **75** (3) (1991) 195–235.

[CGV06] Carrasco, P., Garzón, A. R., and Vitale, E. M., On categorical crossed modules. *Theory Appl. Categ.* **16** (22) (2006) 585–618 (electronic).

[CLV02] Casas, J. M., Ladra, M., and Vieites, A. M., Obstruction theory in crossed modules. *Comm. Algebra* **30** (8) (2002) 3589–3609.

[Čec32] Čech, E., *Höherdimensionale Homotopiegruppen*. Verhandlungen des Internationalen Mathematiker-Kongresses Zurich, Band 2 (1932).

[CGCO02] Cegarra, A. M., García-Calcines, J. M., and Ortega, J. A., On graded categorical groups and equivariant group extensions. *Canad. J. Math.* **54** (5) (2002) 970–997.

[CG07] Cheng, E., and Gurski, N., The periodic table of n-categories for low dimensions. I. Degenerate categories and degenerate bicategories. In *Categories in algebra, geometry and mathematical physics*. Contemp. Math. 431, Amer. Math. Soc., Providence, RI (2007), 143–164.

[Chi11] Chikhladze, D., A category of quantum categories. *Theory Appl. Cat.* **25** (1) (2011) 1–37.

[CCH81] Chiswell, I. M., Collins, D. J., and Huebschmann, J., Aspherical group presentations. *Math. Z.* **178** (1) (1981) 1–36.

[Cis06] Cisinski, D.-C., Les préfaisceaux commes modèles des types d'homotopie. *Astérisque* **308**, Soc. Math. France, Paris (2006).

[Coa74] Coates, R. B., *Semantics of generalised algebraic structures*. Ph.D. thesis, University of London (1974).

[Coh89] Cohen, D. E., *Combinatorial group theory: a topological approach*. London Math. Soc. Student Texts 14, Cambridge University Press, Cambridge (1989).

[Coh73] Cohen, M. M., *A course in simple-homotopy theory*. Grad. Texts in Math. 10. Springer-Verlag, New York (1973).

[Con84] Conduché, D., Modules croisés généralisés de longueur 2, *J. Pure Appl. Algebra*, **34** (1984) 155–178.

[CE89] Conduché, D., and Ellis, G. J., Quelques propriétés homologiques des modules précroisés. *J. Algebra* **123** (2) (1989) 327–335.

[Con72] Conduché, F., Au sujet de l'existence d'adjoints à droite aux foncteurs "image réciproque" dans la catégorie des catégories. *C. R. Acad. Sci. Paris Sér. A-B* **275** (1972) A891–A894.

[Con94] Connes, A., *Noncommutative geometry*. Academic Press Inc., San Diego, CA (1994).

[Cor87] Cordier, J.-M., Homologie de Steenrod-Sitnikov et limite homotopique algébrique. *Manuscripta Math.* **59** (1) (1987) 35–52.

[CP97] Cordier, J.-M., and Porter, T., Homotopy coherent category theory. *Trans. Amer. Math. Soc.* **349** (1) (1997) 1–54.

[Cra99] Crans, S. E., On combinatorial models for higher dimensional homotopies. PhD. Thesis, Utrecht (1995). http://home.tiscali.nl/secrans/papers/comb.html

[Cra99] Crans, S. E., A tensor product for **Gray**-categories. *Theory Appl. Categ.* **5** (2) (1999) 12–69 (electronic).

[CP01] Crisp, J., and Paris, L., The solution to a conjecture of Tits on the subgroup generated by the squares of the generators of an Artin group. *Invent. Math.* **145** (1) (2001) 19–36.

[Cro59] Crowell, R. H., On the van Kampen theorem. *Pacific J. Math.* **9** (1959) 43–50.

[Cro61] Crowell, R. H., Corresponding group and module sequences. *Nagoya Math. J.* **19** (1961) 27–40.

[Cro71] Crowell, R. H., The derived module of a homomorphism. *Adv. Math.* **6** (1971) 210–238 (1971).

[CF63] Crowell, R. H., and Fox, R. H., *Introduction to knot theory*. Grad. Texts in Math. 57, Springer-Verlag, New York (1963).

[CR06] Curtis, C. W., and Reiner, I., *Representation theory of finite groups and associative algebras*. AMS Chelsea Publishing, Providence, RI (2006). Reprint of the 1962 original.

[Dak77] Dakin, M. K., *Kan complexes and multiple groupoid structures*. PhD. Thesis, University of Wales, Bangor (1977).
http://ehres.pagesperso-orange.fr/Cahiers/dakinEM.pdf

[Dan91] Danas, G., *Group extensions and cohomology in cartesian closed categories*. PhD. thesis, City University of New York (1991).

[DP93a] Dawson, R., and Paré, R., Characterizing tileorders. *Order* **10** (2) (1993) 111–128.

[DP93b] Dawson, R., and Paré, R., General associativity and general composition for double categories. *Cahiers Topologie Géom. Différentielle Catég.* **34** (1) (1993) 57–79.

[Day70] Day, B. J., *Construction of Biclosed Categories.* PhD Thesis, University of New South Wales, 1970. http://www.math.mq.edu.au/~street/DayPhD.pdf

[Day70a] Day, B. J., On closed categories of functors. In *Reports of the Midwest Category Seminar IV*, Lecture Notes in Math. 137, Springer-Verlag, Berlin (1970), 1–38.

[Day72] Day, B. J., A reflection theorem for closed categories. *J. Pure Appl. Algebra* **2** (1972) 1–11.

[Ded58] Dedecker, P., Cohomologie de dimension 2 à coefficients non abéliens. *C. R. Acad. Sci. Paris* **247** (1958) 1160–1163.

[Ded60] Dedecker, P., Sur la cohomologie non abélienne. I. *Canad. J. Math.* **12** (1960) 231–251.

[Ded63] Dedecker, P., Sur la cohomologie non abélienne. II. *Canad. J. Math.* **15** (1963) 84–93.

[Ded64] Dedecker, P., Les foncteurs Ext_{Π}, ${\rm H}_{\Pi}{}^2$ et $H_{\Pi}{}^2$ non abéliens. *C. R. Acad. Sci. Paris* **258** (1964) 4891–4894.

[Die89] Dieudonné, J., *A history of algebraic and differential topology. 1900–1960.* Birkhäuser, Boston, MA (1989).

[Dol58] Dold, A., Homology of symmetric products and other functors of complexes. *Ann. of Math.* (2) **68** (1958) 54–80.

[Dol95] Dold, A., *Lectures on algebraic topology*. Classics in Mathematics, Springer-Verlag, Berlin (1995). Reprint of the 1972 edition.

[Dus75] Duskin, J., Simplicial methods and the interpretation of "triple" cohomology. *Mem. Amer. Math. Soc.* **3** (issue 2, 163) (1975).

[DS95] Dwyer, W. G., and Spaliński, J., Homotopy theories and model categories. In *Handbook of algebraic topology*, North-Holland, Amsterdam (1995), 73–126.

[DV73] Dyer, E., and Vasquez, A. T., Some small aspherical spaces. *J. Austral. Math. Soc.* **16** (1973) 332–352. Collection of articles dedicated to the memory of Hanna Neumann, III.

[EH62] Eckmann, B., and Hilton, P. J., Group-like structures in general categories. I. Multiplications and comultiplications. *Math. Ann.* **145** (1961/1962) 227–255.

[EP97] Ehlers, P. J., and Porter, T., Varieties of simplicial groupoids. I. Crossed complexes. *J. Pure Appl. Algebra* **120** (3) (1997) 221–233.

[EV08] Ehresmann, A., and Vanbremeersch, J. P., *Memory evolutive systems: hierarchy, emergence, cognition*. Studies in Multidisciplinarity 4, Elsevier, Amsterdam (2008).

[Ehr57] Ehresmann, C., Gattungen von lokalen Strukturen. *Jahresber. Deutsch. Math. Verein.* **60** (1) (1957) 49—77.

[Ehr65] Ehresmann, C., *Catégories et structures*. Dunod, Paris (1965).

[Ehr83] Ehresmann, C., Œuvres complètes et commentées. I-1, 2. Topologie algébrique et géométrie différentielle. *Cahiers Topologie Géom. Différentielle* **24** (suppl. 1) (1983) [(1984)], with commentary by W. T. van Est, M. Zisman, G. Reeb, P. Libermann, R. Thom, J. Pradines, R. Hermann, A. Kock, A. Haefliger, J. Bénabou, R. Guitart, and A. C. Ehresmann, edited by A. C. Ehresmann.

[Eil44] Eilenberg, S., Singular homology theory. *Ann. of Math.* (2) **45** (1944) 407–447.

[Eil47] Eilenberg, S., Homology of spaces with operators. I. *Trans. Amer. Math. Soc.* **61** (1947) 378–417; errata, 62, 548 (1947).

[EK66] Eilenberg, S., and Kelly, G. M., Closed categories. In *Proc. Conf. Categorical Algebra* (La Jolla, Calif., 1965), Springer-Verlag, New York (1966), 421–562.

[EML45a] Eilenberg, S., and Mac Lane, S., General theory of natural equivalences. *Trans. Amer. Math. Soc.* **58** (1945) 231–294.

[EML45b] Eilenberg, S., and MacLane, S., Relations between homology and homotopy groups of spaces. *Ann. of Math.* (2) **46** (1945) 480–509.

[EML47] Eilenberg, S., and Mac Lane, S., Cohomology theory in abstract groups. I. *Ann. of Math.* (2) **48** (1947) 51–78.

[EML49] Eilenberg, S., and Mac Lane, S., Homology of spaces with operators. II. *Trans. Amer. Math. Soc.* **65** (1949) 49–99.

[EML50] Eilenberg, S., and Mac Lane, S., Relations between homology and homotopy groups of spaces. II. *Ann. of Math.* (2) **51** (1950) 514–533.

[EML53a] Eilenberg, S., and Mac Lane, S., Acyclic models. *Amer. J. Math.* **75** (1953) 189–199.

[EML53b] Eilenberg, S., and Mac Lane, S., On the groups $H(\pi, n)$. I. *Ann. of Math.* (2) **58** (1953) 55–106.

[EZ53] Eilenberg, S., and Zilber, J. A., On products of complexes. *Amer. J. Math.* **75** (1953) 200–204.

[Ell93] Ellis, G., Crossed squares and combinatorial homotopy. *Math. Z.* **214** (1) (1993) 93–110.

[Ell04] Ellis, G., Computing group resolutions. *J. Symbolic Comput.* **38** (3) (2004) 1077–1118.

[Ell08] Ellis, G., Homological algebra programming. (2008) http://hamilton.nuigalway.ie/Hap/www/

[EM10] Ellis, G., and Mikhailov, R., A colimit of classifying spaces. *Adv. Math.* **223** (6) (2010) 2097–2113.

[Ell88a] Ellis, G. J., The group $K_2(\Lambda; I_1, \dots, I_n)$ and related computations. *J. Algebra* **112** (2) (1988) 271–289.

[Ell88b] Ellis, G. J., Homotopy classification the J. H. C. Whitehead way. *Exposition. Math.* **6** (2) (1988) 97–110.

[EP86] Ellis, G. J., and Porter, T., Free and projective crossed modules and the second homology group of a group. *J. Pure Appl. Algebra* **40** (1) (1986) 27–31.

[ES87] Ellis, G. J., and Steiner, R., Higher-dimensional crossed modules and the homotopy groups of $(n+1)$-ads. *J. Pure Appl. Algebra* **46** (2-3) (1987) 117–136.

[Eps66] Epstein, D. B. A., Semisimplicial objects and the Eilenberg-Zilber theorem. *Invent. Math.* **1** (1966) 209–220.

[EW07] Evans, G. A., and Wensley, C. D., Complete involutive rewriting systems. *J. Symbolic Comput.* **42** (11-12) (2007) 1034–1051.

[EGVdL08] Everaert, T., Gran, M., and Van der Linden, T., Higher Hopf formulae for homology via Galois theory. *Adv. Math.* **217** (5) (2008) 2231–2267.

[EKVdL06] Everaert, T., Kieboom, R. W., and Van der Linden, T., Model structures for homotopy of internal categories. *Theory Appl. Categ.* **15** (3) (2005/06) 66–94 (electronic).

[Evr76] Evrard, M., Homotopie des complexes simpliciaux et cubiques. Preprint (1976).

[FM07] Faria Martins, J., A new proof of a realisation theorem of H.-J. Baues. Preprint (2007) 1–16.

[FM09] Faria Martins, J., The fundamental crossed module of the complement of a knotted surface. *Trans. Amer. Math. Soc.* **361** (9) (2009) 4593–4630.

[FM11] Faria Martins, J., The fundamental 2-crossed complex of a reduced CW-complex. Preprint (2011) 1–30.

[FMP11] Faria Martins, J., and Picken, R., Surface holonomy for non-abelian 2-bundles via double groupoids. *Adv. Math.* **226** (2011) 3309–3366.

[FRS95] Fenn, R., Rourke, C., and Sanderson, B., Trunks and classifying spaces. *Appl. Categ. Structures* **3** (4) (1995) 321–356.

[FR05] Forester, M., and Rourke, C., Diagrams and the second homotopy group. *Comm. Anal. Geom.* **13** (4) (2005) 801–820.

[Fox53] Fox, R. H., Free differential calculus. I. Derivation in the free group ring. *Ann. of Math.* (2) **57** (1953) 547–560.

[Fre72] Freyd, P., Aspect of topoi. *Bull. Austral. Math. Soc.* **7** (1972) 1–76.

[GZ67] Gabriel, P., and Zisman, M., *Calculus of fractions and homotopy theory*. Ergeb. Math. Grenzgeb. 35, Springer-Verlag, New York (1967).

[GAP08] The GAP Group. *GAP – Groups, algorithms, and programming, Version 4.4.12* (2008).

[Gar80] Gardner, R., Review of "Invariant theory", by J.A. Springer. *Bull. Amer. Math. Soc.* **2** (1980) 246–256.

[Gil87] Gilbert, N. D., On the fundamental cat^n-group of an n-cube of spaces. In *Algebraic topology* (Barcelona, 1986), Lecture Notes in Math. 1298, Springer-Verlag, Berlin (1987), 124–139.

[GH89] Gilbert, N. D., and Higgins, P. J., The nonabelian tensor product of groups and related constructions. *Glasgow Math. J.* **31** (1) (1989) 17–29.

[Gir64] Giraud, J., Méthode de la descente. *Bull. Soc. Math. France Mém.* **2** (1964) viii+150.

[Gle82] Glenn, Paul G., Realization of cohomology classes in arbitrary exact categories. *J. Pure Appl. Algebra* **25** (1982) 33-–105.

[GJ99] Goerss, P. G., and Jardine, J. F., *Simplicial homotopy theory*. Progr. Math. 174, Birkhäuser, Basel (1999).

[GS06] Golubitsky, M., and Stewart, I., Nonlinear dynamics of networks: the groupoid formalism. *Bull. Amer. Math. Soc.* (*N.S.*) **43** (3) (2006) 305–364.

[Goo92] Goodwillie, T. G., Calculus. II. Analytic functors. *K-Theory* **5** (4) (1991/92) 295–332.

[Got69] Gottlieb, D. H., Covering transformations and universal fibrations. *Illinois J. Math.* **13** (1969) 432–437.

[Gou03] Goubault, E., Some geometric perspectives in concurrency theory. Algebraic topological methods in computer science (Stanford, CA, 2001), *Homology Homotopy Appl.* **5** (2) (2003) 95–136.

[GL01] Grabmeier, J., and Lambe, L. A., Computing resolutions over finite p-groups. In *Algebraic combinatorics and applications* (Gößweinstein, 1999), Springer-Verlag, Berlin (2001), 157–195.

[Gra92] Gramain, A., Le théorème de van Kampen. *Cahiers Topologie Géom. Différentielle Catég.* **33** (3) (1992) 237–251.

[GM03] Grandis, M., and Mauri, L., Cubical sets and their site. *Theory Appl. Categ.* **11** (2003) 185–201.

[Gra66] Gray, J. W., Fibred and cofibred categories. In *Proc. Conf. Categorical Algebra* (La Jolla, Calif., 1965), Springer-Verlag, New York (1966), 21–83.

[Gro68] Grothendieck, A., *Catégories cofibrées additives et complexe cotangent relatif.* Lecture Notes in Math. 79, Springer-Verlag, Berlin (1968).

[Gro89] Grothendieck, A., *Les Dérivateurs*. Edited by M. Künzer, J. Malgoire, G. Maltsiniotis (1989), c. 2000 pages.
http://www.math.jussieu.fr/ maltsin/groth/Derivateurs.html

[Gro97] Grothendieck, A., Esquisse d'un programme. In *Geometric Galois actions*, 1. London Math. Soc. Lecture Note Ser. 242. Cambridge University Press, Cambridge (1997), 5–48 (with an English translation on pp. 243–283).

[GroPS1] Grothendieck, A., Pursuing stacks. Manuscrit, edited by G. Maltsiniotis, to appear in *Documents Mathématiques*.

[GroPS2] Grothendieck, A., Pursuing stacks et correspondance. Manuscrits, edited by M. Künzer, G. Maltsiniotis and B. Toen, to appear in *Documents Mathématiques*.

[Gru57] Gruenberg, K., Residual properties of infinite soluble groups. *Proc. London Math. Soc.* (3) **7** (1957) 29–62.

[GR80] Gruenberg, K. W., and Roggenkamp, K. W., Extension categories of groups and modules. II. Stem extensions. *J. Algebra* **67** (2) (1980) 342–368.

[Gug57] Gugenheim, V. K. A. M., On supercomplexes. *Trans. Amer. Math. Soc.* **85** (1957) 35–51.

[GM57] Gugenheim, V. K. A. M., and Moore, J. C., Acyclic models and fibre spaces. *Trans. Amer. Math. Soc.* **85** (1957) 265–306.

[GNAPGP88] Guillén, F., Navarro Aznar, V., Pascual Gainza, P., and Puerta, F., *Hyperrésolutions cubiques et descente cohomologique*. Papers from the Seminar on Hodge-Deligne Theory held in Barcelona, 1982, Lecture Notes in Math. 1335, Springer-Verlag, Berlin (1988).

[GSNPR08] Guillén Santos, F., Navarro, V., Pascual, P., and Roig, A., Monoidal functors, acyclic models and chain operads. *Canad. J. Math.* **60** (2) (2008) 348–378.

[GWL81] Guin-Waléry, D., and Loday, J.-L., Obstruction à l'excision en K-théorie algébrique. In *Algebraic K-theory* (Evanston 1980), Lecture Notes in Math. 854. Springer-Verlag, Berlin (1981), 179–216.

[GM09] Guiraud, Y., and Malbos, P., Higher dimensional categories with finite derivation type. *Theory Appl. Cat.* **22** (18) (2009) 420–478.

[GM10] Guiraud, Y., and Malbos, P., Coherence in monoidal track categories. arXiv:1004.1055v2 [math.CT] (2010) 1–22.

[GH86] Gutiérrez, M. A., and Hirschhorn, P. S., Free simplicial groups and the second relative homotopy group of an adjunction space. *J. Pure Appl. Algebra* **39** (1-2) (1986) 119–123.

[Hae92] Haefliger, A., Extension of complexes of groups. *Ann. Inst. Fourier* (*Grenoble*) **42** (1-2) (1992) 275–311.

[HW08] Haglund, F., and Wise, D. T., Special cube complexes. *Geom. Funct. Anal.* **17** (5) (2008) 1551–1620.

[Hat02] Hatcher, A., *Algebraic topology*. Cambridge University Press, Cambridge (2002).

[Hea05] Heath, P. R., Fibre techniques in Nielsen theory calculations. In *Handbook of topological fixed point theory*, Springer-Verlag, Dordrecht (2005), 489–554.

[HK81] Heath, P. R., and Kamps, K. H., Groupoids, stability cokernel sequences and duality. Third Colloquium on Categories (Amiens, 1980), Part II, *Cahiers Topologie Géom. Différentielle* **22** (1) (1981) 97–104.

[HK82] Heath, P. R., and Kamps, K. H., On exact orbit sequences. *Illinois J. Math.* **26** (1) (1982) 149–154.

[HK89] Heath, P. R., and Kamps, K. H., Lifting colimits of (topological) groupoids and (topological) categories. In *Categorical topology and its relation to analysis, algebra and combinatorics* (Prague, 1988), World Sci. Publ., Teaneck, NJ (1989), 54–88.

[HR99] Heyworth, A., and Reinert, B., Applications of Gröbner bases to group rings and identities among relations. Bangor Maths. Preprint 99.09.

[HW03] Heyworth, A., and Wensley, C. D., Logged rewriting and identities among relators. In *Groups St. Andrews 2001 in Oxford*, Vol. I, London Math. Soc. Lecture Note Ser. 304, Cambridge University Press, Cambridge (2003), 256–276.

[Hig63] Higgins, P. J., Algebras with a scheme of operators. *Math. Nachr.* **27** (1963) 115–132.

[Hig64] Higgins, P. J., Presentations of groupoids, with applications to groups. *Proc. Cambridge Philos. Soc.* **60** (1964) 7–20.

[Hig71] Higgins, P. J., *Notes on categories and groupoids*. Mathematical Studies 32, Van Nostrand Reinhold Co. London (1971); Reprints in *Theory Appl. Categ.* **7** (2005), 1–195,.

[Hig76] Higgins, P. J., The fundamental groupoid of a graph of groups. *J. London Math. Soc.* (2) **13** (1) (1976) 145–149.

[Hig05] Higgins, P. J., Thin elements and commutative shells in cubical ω-categories. *Theory Appl. Categ.* **14** (4) (2005) 60–74 (electronic).

[HT82] Higgins, P. J., and Taylor, J., The fundamental groupoid and the homotopy crossed complex of an orbit space. In Category theory (Gummersbach, 1981), *Lecture Notes in Math.*, Volume 962. Springer-Verlag, Berlin (1982), 115–122.

[HW60] Hilton, P. J., and Wylie, S., *Homology theory, an introduction to algebraic topology*. Cambridge University Press, London (1960).

[Hin73] Hintze, S., *Polysets, □-sets and semi-cubical sets*. M.Phil thesis, University of Warwick (1973).

[HO09] Hirashima, Y., and Oda, N., Brown-Booth-Tillotson theory for classes of exponentiable spaces. *Topology Appl.* **156** (13) (2009) 2264–2283.

[Hir03] Hirschhorn, P. S., *Model categories and their localizations*. Math. Surveys Monogr. 99, Amer. Math. Soc., Providence, RI (2003).

[HAMS93] Hog-Angeloni, C., Metzler, W., and Sieradski, A. J. (eds.), *Two-dimensional homotopy and combinatorial group theory*. London Math. Soc. Lecture Note Ser. 197, Cambridge University Press, Cambridge (1993).

[Hol79] Holt, D. F., An interpretation of the cohomology groups $H^n(G, M)$. *J. Algebra* **60** (2) (1979) 307–320.

[Hop42] Hopf, H., Fundamentalgruppe und zweite Bettische Gruppe. *Comment. Math. Helv.* **14** (1942) 257–309.

[Hor79] Horadam, K. J., The mapping cylinder resolution for a groupnet diagram. *J. Pure Appl. Algebra* **15** (1) (1979) 23–40.

[Hov99] Hovey, M., *Model categories*. Math. Surveys Monogr. 63, Amer. Math. Soc., Providence, RI (1999).

[How79] Howie, J., Pullback functors and crossed complexes. *Cahiers Topologie Géom. Différentielle* **20** (3) (1979) 281–296.

[Hu48] Hu, S.-T., On the Whitehead group of automorphisms of the relative homotopy groups. *Portugaliae Math.* **7** (1948) 181–206 (1950).

[Hu53] Hu, S.-T., The homotopy addition theorem. *Ann. of Math.* (2) **58** (1953) 108–122.

[Hu59] Hu, S.-T., *Homotopy theory*. Pure and Applied Mathematics VIII, Academic Press, New York (1959).

[Hue77] Huebschmann, J., *Verschränkte n-fache Erweiterungen von Gruppen und Cohomologie*. Ph.D. thesis, ETH Zurich (1977).

[Hue80a] Huebschmann, J., Crossed n-fold extensions of groups and cohomology. *Comment. Math. Helv.* **55** (2) (1980) 302–313.

[Hue80b] Huebschmann, J., The first k-invariant, Quillen's space BG^+, and the construction of Kan and Thurston. *Comm. Math. Helv.* **55** (1980) 314–318.

[Hue81a] Huebschmann, J., Automorphisms of group extensions and differentials in the Lyndon-Hochschild-Serre spectral sequence. *J. Algebra* **72** (2) (1981) 296–334.

[Hue81b] Huebschmann, J., Group extensions, crossed pairs and an eight term exact sequence. *J. Reine Angew. Math.* **321** (1981) 150–172.

[Hue89] Huebschmann, J., Cohomology of nilpotent groups of class 2. *J. Algebra* **126** (2) (1989) 400–450.

[Hue91] Huebschmann, J., Cohomology of metacyclic groups. *Trans. Amer. Math. Soc.* **328** (1) (1991) 1–72.

[Hue99] Huebschmann, J., Extended moduli spaces, the Kan construction, and lattice gauge theory. *Topology* **38** (3) (1999) 555–596.

[Hue07] Huebschmann, J., Origins and breadth of the theory of higher homotopies. In *Higher structures in geometry and physics*. In honor of Murray Gerstenhaber and Jim Stasheff, Progr. Math. 287, Birkhäuser/Springer, New York (2011), 159–179.

[Hue09] Huebschmann, J., Braids and crossed modules. arXiv:0904.3895v2 [math.AT] (2009) 1–17.

[Hur35] Hurewicz, W., Beiträge zur Topologie der Deformationen. *Nederl. Akad. Wetensch. Proc. Ser. A* **38** (1935) 112–119,521–528.

[Ina97] Inassaridze, H., *Non-abelian homological algebra and its applications*. Math. Appl. 421, Kluwer Academic Publishers, Dordrecht (1997).

[Isa11] Isaacson, S. B., Symmetric cubical sets. *J. Pure Appl. Algebra* **215** (2011), 1146–1173.

[Ive86] Iversen, B., *Cohomology of sheaves*. Universitext, Springer-Verlag, Berlin (1986).

[Jac43] Jacobson, N., *The theory of rings*. Amer. Math. Soc. Math. Surveys I, Amer. Math. Soc., New York (1943).

[Jaj80] Jajodia, S., Homotopy classification of lens spaces for one-relator groups with torsion. *Pacific J. Math.* **89** (1980) (2) 301–311.

[Jan03] Janelidze, G., Internal crossed modules. *Georgian Math. J.* **10** (1) (2003) 99–114.

[JMT02] Janelidze, G., Márki, L., and Tholen, W., Semi-abelian categories. Category theory 1999 (Coimbra), *J. Pure Appl. Algebra* **168** (2-3) (2002) 367–386.

[Jar06] Jardine, J. F., Categorical homotopy theory. *Homology, Homotopy Appl.* **8** (1) (2006) 71–144 (electronic).

[Joh32] Johansson, I., Über die Invarianz der topologischen Wechselsumme $\alpha_0 - \alpha_1 + \alpha_2 - \alpha_3 + \dots$ gegenüber Dimensionsänderungen. *Avhand. Norske. Vidensk.-Akad.* (1) (1932) 2–8.

[JL01] Johansson, L., and Lambe, L., Transferring algebra structures up to homology equivalence. *Math. Scand.* **89** (2) (2001) 181–200.

[Joh97] Johnson, D. L., *Presentations of groups*. Second edition, London Math. Soc. Student Texts 15, Cambridge University Press, Cambridge (1997).

[Joh03] Johnson, F. E. A., Stable modules and Wall's $D(2)$-problem. *Comment. Math. Helv.* **78** (1) (2003) 18–44.

[Joh04] Johnson, F. E. A., Minimal 2-complexes and the D(2)-problem. *Proc. Amer. Math. Soc.* **132** (2) (2004) 579–586 (electronic).

[Joh09] Johnson, F. E. A., Homotopy classification and the generalized Swan homomorphism. *J. K-Theory* **4** (3) (2009) 491–536.

[Joh02] Johnstone, P. T., *Sketches of an elephant: a topos theory compendium*. Vol. 1, 2, Oxford Logic Guides 43, 44, The Clarendon Press/Oxford University Press, New York, Oxford (2002).

[Jon88] Jones, D. W., A general theory of polyhedral sets and the corresponding T-complexes. *Dissertationes Math.* (*Rozprawy Mat.*) **266** (1988) 110.

[JS91] Joyal, A., and Street, R., The geometry of tensor calculus. I. *Adv. Math.* **88** (1) (1991) 55–112.

[JT07] Joyal, A., and Tierney, M., Quasi-categories vs Segal spaces. In *Categories in algebra, geometry and mathematical physics*, Contemp. Math. 431, Amer. Math. Soc., Providence, RI (2007), 277–326.

[Kam33] Kampen, E. H. v., On the connection between the fundamental groups of some related spaces. *Amer. J. Math.* **55** (1933) 261–267.

[Kam72] Kamps, K. H., Kan-Bedingungen und abstrakte Homotopiethoerie. *Math. Z.* **124** (1972) 215–236.

[KP97] Kamps, K. H., and Porter, T., *Abstract homotopy and simple homotopy theory*. World Scientific Publishing Co. Inc., River Edge, NJ (1997).

[KP02] Kamps, K. H., and Porter, T., 2-groupoid enrichments in homotopy theory and algebra. *K-theory* **25** (2002) 373–409.

[Kan55] Kan, D. M., Abstract homotopy. I. *Proc. Nat. Acad. Sci. U.S.A.* **41** (1955) 1092–1096.

[Kan58a] Kan, D. M., Adjoint functors. *Trans. Amer. Math. Soc.* **87** (1958) 294–329.

[Kan58b] Kan, D. M., Functors involving c.s.s. complexes. *Trans. Amer. Math. Soc.* **87** (1958) 330–346.

[KFM08] Kauffman, L. H., and Faria Martins, J., Invariants of welded virtual knots via crossed module invariants of knotted surfaces. *Compositio Math.* **144** (4) (2008) 1046–1080.

[Kel82] Kelly, G. M., *Basic concepts of enriched category theory*. London Math. Soc. Lecture Note Ser. 64, Cambridge University Press, Cambridge (1982); Reprints in *Theory Appl. Categ.* **10** (2005) 1–136.

[KML71] Kelly, G. M., and Mac Lane, S., Coherence in closed categories. *J. Pure Appl. Algebra* **1** (1) (1971) 97–140.

[KOK+86] Kneser, M., Ojanguren, M., Knus, M.-A., Parimala, R., and Sridharan, R., Composition of quaternary quadratic forms. *Compositio Math.* **60** (2) (1986) 133–150.

[Koc10] Kock, A., Cubical version of combinatorial differential forms. *Appl. Categ. Structures* **18** (2) (2010) 165–183.

[Koz08] Kozlov, D., *Combinatorial algebraic topology*. Algorithms Comput. Math. 21, Springer-Verlag, Berlin (2008).

[KM97] Kriegl, A., and Michor, P. W., *The convenient setting of global analysis*. Math. Surveys Monogr. 53. Amer. Math. Soc., Providence, RI (1997).

[Kün07] Künzer, M., Heller triangulated categories. *Homology, Homotopy Appl.* **9** (2) (2007) 233–320.

[Lab99] Labesse, J.-P., Cohomologie, stabilisation et changement de base. Appendix A by Laurent Clozel and Labesse, and Appendix B by Lawrence Breen. *Astérisque* **257** (1999).

[Lac10] Lack, S., Note on the construction of free monoids. *Appl. Categ. Structures* **18** (1) (2010) 17–29.

[LMW10] Lafont, Y., Métayer, F., and Worytkiewicz, K., A folk model structure on omega-cat. *Adv. Math.* **224** (3) (2010) 1183–1231.

[LS87] Lambe, L. and Stasheff, J., Applications of perturbation theory to iterated fibrations. *Manuscripta Math.* **58** (3) (1987) 363–376.

[Law04] Lawvere, F. W., Functorial semantics of algebraic theories and some algebraic problems in the context of functorial semantics of algebraic theories. *Repr. Theory Appl. Categ.* **5** (2004), 1–121; reprinted from *Proc. Nat. Acad. Sci. U.S.A.* **50** (1963), 869–872, and *Reports of the Midwest Category Seminar. II*, Lecture Notes in Math. 61, Springer-Verlag, Berlin (1968), 41–61.

[Lev40] Levi, F. W., The commutator group of a free product. *J. Indian Math. Soc.* (*N.S.*) **4** (1940) 136–144.

[Lev57] Levi, F. W., Darstellung der Komposition in einer Gruppe als Relation. *Arch. Math.* (*Basel*) **8** (1957) 169—170.

[Lod78] Loday, J.-L., Cohomologie et groupe de Steinberg relatifs. *J. Algebra* **54** (1) (1978) 178–202.

[Lod82] Loday, J.-L., Spaces with finitely many nontrivial homotopy groups. *J. Pure Appl. Algebra* **24** (2) (1982) 179–202.

[Lod00] Loday, J.-L., Homotopical syzygies. In *Une dégustation topologique: homotopy theory in the Swiss Alps* (Arolla, 1999), Contemp. Math. 265. Amer. Math. Soc., Providence, RI (2000), 99–127.

[Lom81] Lomonaco, S. J., Jr., The homotopy groups of knots. I. How to compute the algebraic 2-type. *Pacific J. Math.* **95** (2) (1981) 349–390.

[Lüc87] Lück, W., The geometric finiteness obstruction. *Proc. London Math. Soc.* (3) **54** (2) (1987) 367–384.

[Lue71] Lue, A. S.-T., Cohomology of algebras relative to a variety. *Math. Z.* **121** (1971) 220–232.

[Lue79] Lue, A. S.-T., Semicomplete crossed modules and holomorphs of groups. *Bull. London Math. Soc.* **11** (1) (1979) 8–16.

[Lue81] Lue, A. S.-T., Cohomology of groups relative to a variety. *J. Algebra* **69** (1) (1981) 155–174.

[Lur09] Lurie, J., *Higher topos theory*. Ann. of Math. Stud. 170, Princeton University Press, Princeton, NJ (2009).

[Lyn50] Lyndon, R. C., Cohomology theory of groups with a single defining relation. *Ann. of Math.* (2) **52** (1950) 650–665.

[LS01] Lyndon, R. C., and Schupp, P. E., *Combinatorial group theory*. Reprint of the 1977 edition, Classics in Mathematics, Springer-Verlag, Berlin (2001).

[Mac87] Mackenzie, K., *Lie groupoids and Lie algebroids in differential geometry*. London Math. Soc. Lecture Note Ser. 124, Cambridge University Press, Cambridge (1987).

[Mac05] Mackenzie, K. C. H., *General theory of Lie groupoids and Lie algebroids*. London Math. Soc. Lecture Note Ser. 213, Cambridge University Press, Cambridge (2005).

[ML49] Mac Lane, S., Cohomology theory in abstract groups. III. Operator homomorphisms of kernels. *Ann. of Math.* (2) **50** (1949) 736–761.

[ML63] Mac Lane, S., *Homology*. Grundlehren Math. Wiss. 114, Springer-Verlag, Berlin (1963).

[ML71] Mac Lane, S., *Categories for the working mathematician*. Grad. Texts in Math. 5, Springer-Verlag, New York (1971).

[ML78] Mac Lane, S., Origins of the cohomology of groups. *Enseign. Math.* (2) **24** (1-2) (1978) 1–29.

[ML79] Mac Lane, S., Historical note. *J. Algebra* **69** (1979) 319–320.

[MLM94] Mac Lane, S., and Moerdijk, I., *Sheaves in geometry and logic*. A first introduction to topos theory. Corrected reprint of the 1992 edition, Universitext, Springer-Verlag, New York (1994).

[MLM96] Mac Lane, S., and Moerdijk, I., Topos theory. In *Handbook of algebra, Vol.* 1, North-Holland, Amsterdam (1996), 501–528.

[MLW50] Mac Lane, S., and Whitehead, J. H. C., On the 3-type of a complex. *Proc. Nat. Acad. Sci. U. S. A.* **36** (1950) 41–48.

[Mal05] Maltsiniotis, G., La théorie de l'homotopie de Grothendieck. *Astérisque* **301** (2005).

[Mal09] Maltsiniotis, G., La catégorie cubique avec connexions est une catégorie test stricte. *Homology, Homotopy Appl.* **11** (2) (2009) 309–326.

[MaltDer] Maltsiniotis, G., Introduction à la théorie des dérivateurs (d'après Grothendieck. Preprint http://www.math.jussieu.fr/~maltsin/textes.html

[Man76] Manes, E. G., *Algebraic theories*. Grad. Texts in Math. 26, Springer-Verlag, New York (1976).

[MM10] Mantovani, S., and Metere, G., Internal crossed modules and Peiffer condition. *Theory Appl. Categ.* **23** (2010) 113–135.

[Mas80] Massey, W. S., *Singular homology theory*. Grad. Texts in Math. 70, Springer-Verlag, New York (1980).

[May67] May, J. P., *Simplicial objects in algebraic topology*. Van Nostrand Mathematical Studies 11, D. Van Nostrand Co., Inc., Princeton, N.J.-Toronto, Ont.-London (1967).

[May72] May, J. P., *The geometry of iterated loop spaces*. Lectures Notes in Math. 271, Springer-Verlag, Berlin (1972).

[May77a] May, J. P., *E_∞ ring spaces and E_∞ ring spectra*. With contributions by F. Quinn, N. Ray, and J. Tornehave, Lecture Notes in Math. 577, Springer-Verlag, Berlin (1977).

[May77b] May, J. P., Infinite loop space theory. *Bull. Amer. Math. Soc.* **83** (4) (1977) 456–494.

[May82] May, J. P., Multiplicative infinite loop space theory. *J. Pure Appl. Algebra* **26** (1) (1982) 1–69.

[Maz65] Mazur, B., Morse theory. In *Differential and combinatorial topology* (A Symposium in Honor of Marston Morse), Princeton University Press, Princeton, N.J. (1965), 145–165.

[McC71] McClendon, J. F., Obstruction theory in fiber spaces. *Math. Z.* **120** (1971) 1–17.

[McP69] McPherson, J. M., On the nullity and enclosure genus of wild knots. *Trans. Amer. Math. Soc.* **144** (1969) 545–555.

[Met79] Metzler, W., Äquivalenzklassen von Gruppenbeschreibungen, Identitäten von Relationen und einfacher Homotopietyp in niederen Dimensionen. In *Homological group theory* (Durham, 1977), with an appendix by C. T. C. Wall, London Math. Soc. Lecture Note Ser. 36, Cambridge University Press, Cambridge (1979), 291–326.

[MW10] Mikhailov, R., and Wu, J., On homotopy groups of the suspended classifying spaces. *Algebr. Geom. Topol.* **10** (1) (2010) 565–625.

[Mil71] Milnor, J., *Introduction to algebraic K-theory*. Ann. Math. Stud. 72, Princeton University Press, Princeton, N.J. (1971).

[MOt06] Minian, G., and Ottina, M., A geometric decomposition of spaces into cells of different types. *J. Homotopy Relat. Struct.* **1** (1) (2006) 245–271.

[Mit72] Mitchell, B., Rings with several objects. *Adv. Math.* **8** (1972) 1–161.

[Moo01] Moore, E., *Graphs of groups: word computations and free crossed resolutions*. Ph.D. thesis, University of Wales, Bangor (2001).

[Mos87] Mosa, G. H., *Higher dimensional algebroids and crossed complexes*. Ph.D. thesis, University of Wales, Bangor (1987).

[MP02] Mukherjee, G., and Pandey, N., Equivariant cohomology with local coefficients. *Proc. Amer. Math. Soc.* **130** (1) (2002) 227–232 (electronic).

[MT07] Muro, F., and Tonks, A., The 1-type of a Waldhausen K-theory spectrum. *Adv. Math.* **216** (1) (2007) 178–211.

[MTW10] Muro, F., Tonks, A., and Witte, M., On determinant functors and K-theory. arXiv:1006.5399v1 [math.KT] (2010) 1–71.

[NT89a] Nan Tie, G., A Dold-Kan theorem for crossed complexes. *J. Pure Appl. Algebra* **56** (2) (1989) 177–194.

[NT89b] Nan Tie, G., Iterated $\bar{W}$ and T-groupoids. *J. Pure Appl. Algebra* **56** (2) (1989) 195–209.

[Nee01] Neeman, A., *Triangulated categories*. Ann. Math. Stud. 148, Princeton University Press, Princeton, NJ (2001).

[Nor90] Norrie, K., Actions and automorphisms of crossed modules. *Bull. Soc. Math. France* **118** (2) (1990) 129–146.

[Olu50] Olum, P., Obstructions to extensions and homotopies. *Ann. of Math.* (2) **52** (1950) 1–50.

[Olu53] Olum, P., On mappings into spaces in which certain homotopy groups vanish. *Ann. of Math.* (2) **57** (1953) 561–574.

[Olu58] Olum, P., Non-abelian cohomology and van Kampen's theorem. *Ann. of Math.* (2) **68** (1958) 658–668.

[Pao09] Paoli, S., Weakly globular cat^n-groups and Tamsamani's model. *Adv. Math.* **222** (2) (2009) 621–727.

[Pap63] Papakyriakopoulos, C. D., Attaching 2-dimensional cells to a complex. *Ann. of Math.* (2) **78** (1963) 205–222.

[PRP09] Pascual, P., and Rubió Pons, L., Algebraic K-theory and cubical descent. *Homology, Homotopy Appl.* **11** (2) (2009) 5–25.

[Pat08] Patchkoria, I., Cubical resolutions and derived functors. arXiv:0907.1905v1 [math.KT] (2008) 1–20.

[Pei49] Peiffer, R., Über Identitäten zwischen Relationen. *Math. Ann.* **121** (1949) 67–99.

[PS85] Plotnick, S. P., and Suciu, A. I., k-invariants of knotted 2-spheres. *Comment. Math. Helv.* **60** (1) (1985) 54–84.

[Poi96] Poincaré, H., *Œuvres. Tome VI*. Géométrie. Analysis situs (topologie), reprint of the 1953 edition, Les Grands Classiques, Éditions Jacques Gabay, Gauthier-Villars Sceaux (1996).

[Poi10] Poincaré, H., *Papers on topology: analysis situs and its five supplements*. Translated by John C. Stillwell, History of Mathematics 37, Amer. Math. Soc., Providence, RI/London Math. Soc., London (2010).

[Pon09] Ponto, K., Relative fixed point theory. *Algebr. Geom. Topol.* **11** (2011) 839–886.

[PS09] Ponto, K., and Shulman, M., Shadows and traces in bicategories. arXiv:0910.1306v1 [math.CT] (2009) 1–63.

[Por87] Porter, T., Extensions, crossed modules and internal categories in categories of groups with operations. *Proc. Edinburgh Math. Soc.* (2) **30** (3) (1987) 373–381.

[Por93] Porter, T., n-types of simplicial groups and crossed n-cubes. *Topology* **32** (1) (1993) 5–24.

[Por07] Porter, T., Formal homotopy quantum field theories. II. Simplicial formal maps. In *Categories in algebra, geometry and mathematical physics*, Contemp. Math. 431, Amer. Math. Soc., Providence, RI (2007), 375–403.

[Por11] Porter, T., *Crossed menagerie*. (2011) 1–450. http://ncatlab.org/nlab/show/Crossed+Menagerie.

[Por12] Porter, T., *Profinite algebraic homotopy*. Algebra and Applications, Springer-Verlag, to appear.

[PT08] Porter, T., and Turaev, V., Formal homotopy quantum field theories I: formal maps and crossed $\mathcal{C}$-algebras. *J. Homotopy Relat. Struct.* **3** (1) (2008) 113–159.

[Pra07] Pradines, J., In Ehresmann's footsteps: from group geometries to groupoid geometries. In *Geometry and topology of manifolds*, Banach Center Publ. 76, Polish Acad. Sci., Warsaw (2007), 87-–157.

[Pra09] Pratt, V., The Yoneda Lemma as a foundational tool for algebra. Stanford preprint: http://boole.stanford.edu/pub/yon.pdf (2009) 1–18.

[Pup97] Puppe, D., Nachruf auf H. Seifert. *Jahrbuch der Heidelberger Akademie der Wissenschaften* (1997) 139–144.

[Pup99] Puppe, D., Herbert Seifert (1907-1996). In *History of Topology*, North-Holland, Amsterdam (1999), 1021–1028.

[Qui67] Quillen, D. G., *Homotopical algebra*. Lecture Notes in Math. 43. Springer-Verlag, Berlin (1967).

[RW90] Ranicki, A., and Weiss, M., Chain complexes and assembly. *Math. Z.* **204** (2) (1990) 157–185.

[Rat80] Ratcliffe, J. G., Free and projective crossed modules. *J. London Math. Soc.* (2) **22** (1) (1980) 66–74.

[RS76] Razak Salleh, A., *Union theorems for double groupoids and groupoids; some generalisations and applications*. Ph.D. thesis, University of Wales (1976).

[Rei32] Reidemeister, K., *Einführung die kombinatorische Topologie*. F. Vieweg & Sohn, Braunschweig, Berlin (1932); Reprint Chelsea, New York (1950).

[Rei34] Reidemeister, K., Homotopiegruppen von Komplexen. *Abh. Math. Sem. Universität Hamburg* **10** (1934) 211–215.

[Rei49] Reidemeister, K., Über Identitäten von Relationen. *Abh. Math. Sem. Univ. Hamburg* **16** (1949) 114–118.

[Rei50] Reidemeister, K., Complexes and homotopy chains. *Bull. Amer. Math. Soc.* **56** (1950) 297–307.

[Rot08] Rota, G.-C., *Indiscrete thoughts*. Modern Birkhäuser Classics, Birkhäuser, Boston, MA (2008); Reprint of the 1997 edition, with forewords by Reuben Hersh and Robert Sokolowski, edited, with notes and an epilogue by Fabrizio Palombi.

[RS71] Rourke, C. P., and Sanderson, B. J., $\triangle$-sets. I. Homotopy theory. *Quart. J. Math. Oxford Ser.* (2) **22** (1971) 321–338.

[Sau03] Sauvageot, O., *Stabilisation des complexes croisés*. Ph.D. thesis, École Polytechnique Fédérale de Lausanne (2003).

[Sch73] Schellenberg, B., The group of homotopy self-equivalences of some compact CW-complexes. *Math. Ann.* **200** (1973) 253–266.

[Sch76] Schön, R., Acyclic models and excision. *Proc. Amer. Math. Soc.* **59** (1) (1976) 167–168.

[Sch91] Schön, R., Effective algebraic topology. *Mem. Amer. Math. Soc.* **92** (451) (1991) vi+63.

[Sch37] Schumann, H.-G., Über Moduln und Gruppenbilder. *Math. Ann.* **114** (1) (1937) 385–413.

[Seg99] Segal, S., Topologists in Hitler's Germany. In *History of Topology*, North-Holland, Amsterdam (1999), 849–862.

[Seh03] Sehgal, S. K., Group rings. In *Handbook of algebra, Vol. 3*, North-Holland, Amsterdam (2003), 455–541.

[Sei31] Seifert, H., Konstruktion dreidimensionaler geschlossener Räume. *Berichte Sächs. Akad. Leipzig, Math.-Phys. Kl.* **83** (1931) 26–66.

[ST80] Seifert, H., and Threlfall, W., *Seifert and Threlfall: a textbook of topology*. Pure Appl. Math. 89, Academic Press Inc. New York (1980), translated from the German edition of 1934 by Michael A. Goldman; with a preface by Joan S. Birman, with "Topology of 3-dimensional fibered spaces" by Seifert, translated from the German by Wolfgang Heil.

[Sha93] Sharko, V. V., *Functions on manifolds. Algebraic and topological aspects*. Translated from the Russian by V. V. Minachin. Transl. Math. Monogr. 131. Amer. Math. Soc., Providence, RI (1993).

[Shi62] Shih, W., Homologie des espaces fibrés. *Inst. Hautes Études Sci. Publ. Math.* (13) (1962) 88.

[Shu09] Shulman, M. A., Homotopy limits and colimits and enriched homotopy theory. arXiv:0610194v3 [math.AT] (2009) 1–79.

[Smi51a] Smith, P. A., The complex of a group relative to a set of generators. I. *Ann. of Math.* (2) **54** (1951) 371–402.

[Smi51b] Smith, P. A., The complex of a group relative to a set of generators. II. *Ann. of Math.* (2) **54** (1951) 403–424.

[Sol90] Soloviev, S. V., On the conditions of full coherence in closed categories. *J. Pure Appl. Algebra* **69** (3) (1990) 301–329.

[Sol97] Soloviev, S. V., Proof of a conjecture of S. Mac Lane. *Ann. Pure Appl. Logic* **90** (1-3) (1997) 101–162.

[Spe77] Spencer, C. B., An abstract setting for homotopy pushouts and pullbacks. *Cahiers Topologie Géom. Différentielle* **18** (4) (1977) 409–429.

[SW83] Spencer, C. B., and Wong, Y. L., Pullback and pushout squares in a special double category with connection. *Cahiers Topologie Géom. Différentielle* **24** (2) (1983) 161–192.

[Ste43] Steenrod, N. E., Homology with local coefficients. *Ann. of Math.* (2) **44** (1943) 610–627.

[Ste67] Steenrod, N. E., A convenient category of topological spaces. *Michigan Math. J.* **14** (1967) 133–152.

[Ste72] Steenrod, N. E., Cohomology operations, and obstructions to extending continuous functions. *Adv. Math.* **8** (1972) 371–416.

[Ste06] Steiner, R., Thin fillers in the cubical nerves of omega-categories. *Theory Appl. Categ.* (8) **16** (2006) 144–173 (electronic).

[Str87] Street, R., The algebra of oriented simplexes. *J. Pure Appl. Algebra* **49** (3) (1987) 283–335.

[Str88] Street, R., Gray's tensor product of 2-categories (1988). Handwritten notes.

[SV10] Street, R., and Verity, D., The comprehensive factorization and torsors. *Theory Appl. Categ.* **23** (2010) 42–75.

[Str99] Streicher, T., Fibred categories à la Bénabou. (1999) 1–85.
http://www.mathematik.tu-darmstadt.de/∼streicher/

[Sza78] Szabo, M., *Algebra of proofs*. Studies in Logic and the Foundations of Mathematics 88, North-Holland P.C. (1978).

[Tab09] Tabuada, G., Postnikov towers, k-invariants and obstruction theory for dg categories. *J. Algebra* **321** (12) (2009) 3850–3877.

[Tab10] Tabuada, G., Homotopy theory of dg categories via localizing pairs and Drinfeld's dg quotient. *Homology, Homotopy Appl.* **12** (1) (2010) 187–219.

[Tay53] Taylor, R. L., Compound group extensions. I. Continuations of normal homomorphisms. *Trans. Amer. Math. Soc.* **75** (1953) 106–135.

[Tay54] Taylor, R. L., Covering groups of nonconnected topological groups. *Proc. Amer. Math. Soc.* **5** (1954) 753–768.

[Tay55] Taylor, R. L., Compound group extensions. III. *Trans. Amer. Math. Soc.* **79** (1955) 490–520.

[TW95] Thévenaz, J., and Webb, P., The structure of Mackey functors. *Trans. Amer. Math. Soc.* **347** (6) (1995) 1865–1961.

[tD08] tom Dieck, T., *Algebraic topology*. EMS Textbooks in Mathematics. European Mathematical Society (EMS), Zürich (2008).

[tDKP70] tom Dieck, T., Kamps, K. H., and Puppe, D., *Homotopietheorie*. Lecture Notes in Math. 157, Springer-Verlag, Berlin (1970).

[Ton92] Tonks, A., Cubical groups which are Kan. *J. Pure Appl. Algebra* **81** (1) (1992) 83–87.

[Ton94] Tonks, A., *Theory and applications of crossed complexes*. Ph.D. thesis, University of Wales (1994).

[Ton03] Tonks, A. P., On the Eilenberg-Zilber theorem for crossed complexes. *J. Pure Appl. Algebra* **179** (1-2) (2003) 199–220.

[Tur38] Turing, A. M., The extensions of a group. *Compositio Math.* **5** (1938) 357–367.

[Ver08a] Verity, D., Complicial sets characterising the simplicial nerves of strict ω-categories. *Mem. Amer. Math. Soc.* **193** (905) (2008).

[Ver08b] Verity, D. R. B., Weak complicial sets. I. Basic homotopy theory. *Adv. Math.* **219** (4) (2008) 1081–1149.

[Wal65] Wall, C. T. C., Finiteness conditions for CW-complexes. *Ann. of Math.* (2) **81** (1965) 56–69.

[Wei01] Weinstein, A., Groupoids: unifying internal and external symmetry. A tour through some examples. In *Groupoids in analysis, geometry, and physics* (Boulder, CO, 1999), Contemp. Math. 282, Amer. Math. Soc., Providence, RI (2001), 1–19.

[Wei61] Weinzweig, A. E., The fundamental group of a union of spaces. *Pacific J. Math.* **11** (1961) 763–776.

[WA97] Wensley, C., and Alp, M., Xmod, a gap share package for computation with crossed modules. *GAP Manual* (1997) 1355–1420.

[Whi78] Whitehead, G. W., *Elements of homotopy theory*. Grad. Texts in Math. 61, Springer-Verlag, New York (1978).

[Whi39] Whitehead, J. H. C., Simplicial spaces, nuclei, and m-groups. *Proc. London Math. Soc.* **45** (1939) 243–327.

[Whi41a] Whitehead, J. H. C., On adding relations to homotopy groups. *Ann. of Math.* (2) **42** (1941) 409–428.

[Whi41b] Whitehead, J. H. C., On incidence matrices, nuclei and homotopy types. *Ann. of Math.* (2) **42** (1941) 1197–1239.

[Whi46] Whitehead, J. H. C., Note on a previous paper entitled "On adding relations to homotopy groups.". *Ann. of Math.* (2) **47** (1946) 806–810.

[Whi48] Whitehead, J. H. C., On operators in relative homotopy groups. *Ann. of Math.* (2) **49** (1948) 610–640.

[Whi49a] Whitehead, J. H. C., Combinatorial homotopy. I. *Bull. Amer. Math. Soc.* **55** (1949) 213–245.

[Whi49b] Whitehead, J. H. C., Combinatorial homotopy. II. *Bull. Amer. Math. Soc.* **55** (1949) 453–496.

[Whi50a] Whitehead, J. H. C., On group extensions with operators. *Quart J. Math., Oxford Ser.* (2) **1** (1950) 219–228.

[Whi50b] Whitehead, J. H. C., Simple homotopy types. *Amer. J. Math.* **72** (1950) 1–57.

[Whi50c] Whitehead, J. H. C., A certain exact sequence. *Ann. of Math.* (2) **52** (1950) 51–110.

[Woo10] Woolf, J., Transversal homotopy theory. *Theory Appl. Categ.* **24** (7) (2010) 148–178.

[Zas49] Zassenhaus, H., *The Theory of Groups*. Translated from the German by Saul Kravetz, Chelsea Publishing Company, New York, N. Y. (1949).

[Živ06] Živaljević, R. T., Groupoids in combinatorics—applications of a theory of local symmetries. In *Algebraic and geometric combinatorics*, Contemp. Math. 423, Amer. Math. Soc., Providence, RI (2006), 305–324.