Zometool Project Series: the world's most powerful (and fun!) modeling system. Kids, educators, and Nobel-prize winning scientists all love Zometool:

- it's unique, brilliant, beautiful
- all kits are compatible—more parts, more power!
- guaranteed for life!

"The mind, once stretched by a new idea, never regains its original dimensions." – Oliver Wendell Holmes

Expand your Zome Universe! This kit adds new dimensions* to your Zometool collection and new horizons to your mind.

When combined with other Zometool kits, you can build:

- Regular tetrahedra and octahedra
- Archimedian solids
- Relationships among Platonic Solids
- Amazing duals, compounds etc.
- Oct-tet trusses and much more!

Warning! This ADVANCED KIT is for experienced Zometool users only!

*30 new dimensions, actually
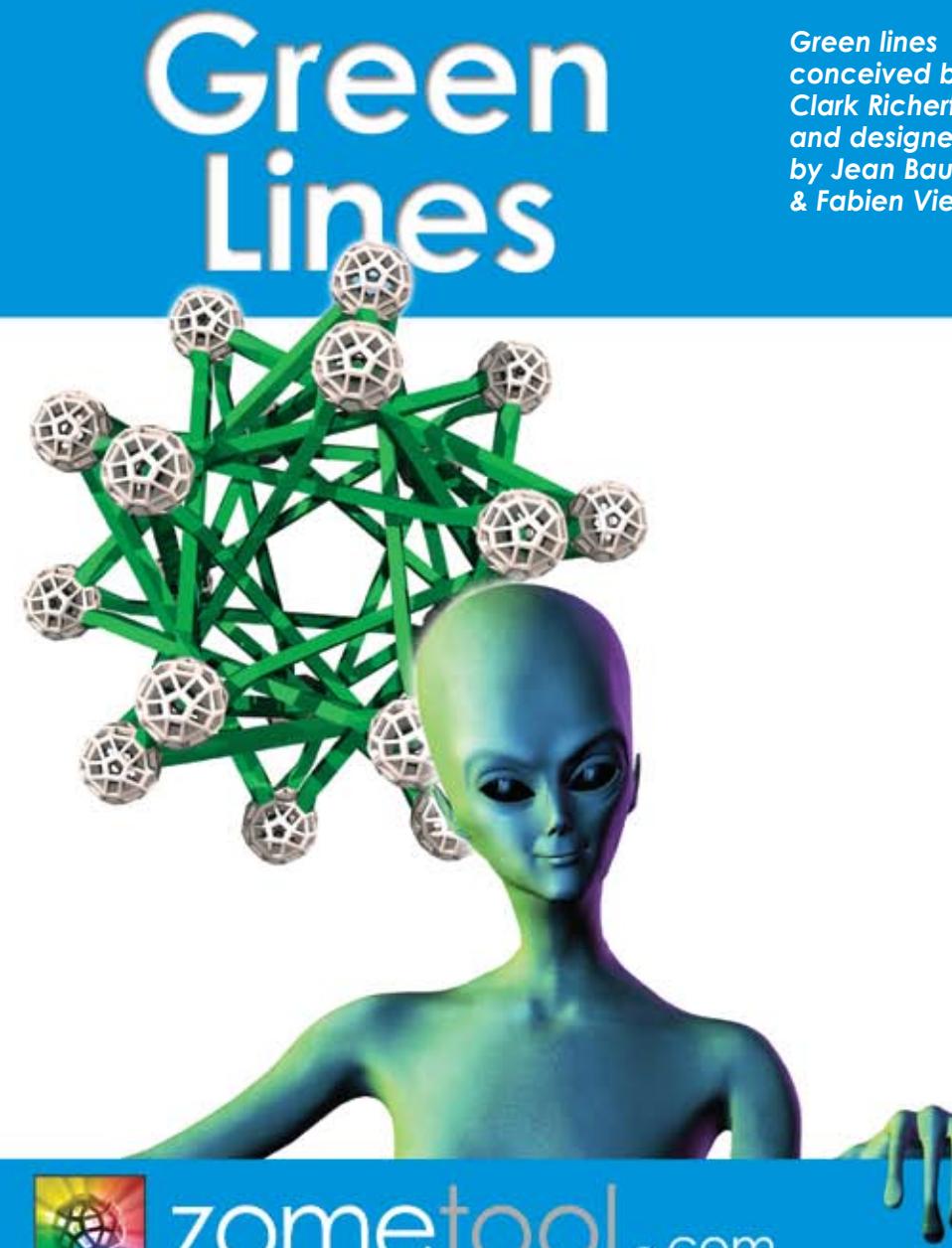
Green Lines

Green lines conceived by Clark Richert and designed by Jean Baudoin & Fabien Vienne

Parts: 222

|	
60	
6	
12	
48	
48	
48	

zometool.com

888-966-3386
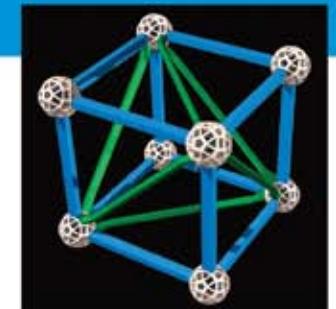
Brace yourself

Cut across a square lawn and you'll use a green line: the fastest way from one corner to the opposite corner of a square. Nail a cross-brace to a square frame — you'll also use a green line: the fastest way from an unstable shape to a rigid structure.

Take 6 braced squares, join the edges and you get a cube with a tetrahedron inside (see Tetrahedron, inside.) Find 5 such cubes in a dodecahedron, and you begin to see the power of Zometool Green Lines! (See 5 Tetras, inside.)

Five tetrahedra associated with 5 cubes of the dodecahedron.

Not easy being green

Look at the end of a green strut. It has a diamond cross-section, yet goes into a *pentagonal hole*, the *same* hole a red strut uses. Because it's "kinked," each green line can take 5 different positions in one pentagonal hole. Try it for yourself:

5 positions of a green line

You can use a framework built from blue lines to orient yourself. Note the position of the green lines in relation to blue lines to "stay on track" with more complicated models.

Details of tetrahedron corner (A) and octahedron corner (B) show green green line symmetry in relation to the cube.

Why not make balls with 30 extra holes to fit all the greens? Well, they're hell to make, and balls with so many holes result in "ball-heavy" models. Most people agree that green lines work pretty well, once you get to know them[1].

Completing Plato

This kit is designed to supplement the blue, yellow and red lines in Zometool System kits. You can build the first two models shown on the other side using only parts included in this kit. The *octahedron* and the *tetrahedron* are two of 5 regular (Platonic) solids built with green lines (you can build the other three—the cube, dodecahdron and icosahedron—using blue lines.)
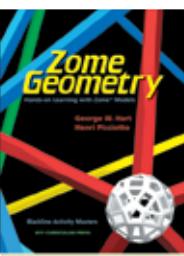
The rest of the models on the other side are cited in Zome Geometry, the Zometool textbook. Title bars for these models are yellow, and the numbers in each title bar refer to the relevant section of the book. You don't need to buy the book in order to build the models— you just need enough Zometool components in your collection (there are enought greens in this kit to build all the models inside).

Zome Geometry

When greens get the blues

You can't build a regular octagon (the STOP sign shape) with this kit. You would need some struts with the same *length* as a *blue* line, but the same *direction* as a *green* line. We call them "blue-greens," but we hardly make them, because people hardly use them[2].

In addition to the regular octagon, you would need blue-greens to make all five regular (Platonic) solids with the same edge length, and some of the semi-regular (Archimedean) solids. But none of these shapes are part of Zometool geometry. So even though you could use blue greens to build a stop sign, they're really a dead end! With blue greens, the parts don't line up the way they do in real Zometool structures.

You can substitute green lines any place you would use blue-greens and build pretty good approximations of the semi-regular solids, etc. The *truncated cube, truncated tetrahedron* and *truncated octahedron* shown on the other side are examples of these *almost* semi-regulars.

Irrational Greeks

How long is a green line? Ancient Babylonians provided an approximation to 4 decimal places, but the Greek philosopher Hippasus discovered that whatever the accuracy, it was never exact ("by numbers this cannot be done".[3]) A disciple of Pythagoras, he found that the square root of 2 — the length of a green line—cannot be expressed as a ratio of whole numbers.
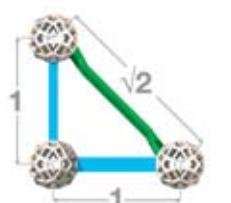
The Pythagoreans had preached that all numbers *could* be expressed as ratios. Though Hippasus was right, the Pythagoreans treated his discovery as religious heresy and either exiled or murdered him. Legend has it that while at sea his fellow Pythagoreans threw him overboard.

While the length of a green line ($\sqrt{2}$) seems to be the "first" irrational number, a worthy challenger is the Divine Proportion (($\sqrt{5}+1)/2$), also known to the Pythagoreans. With Zometool, you get both: green lines come in Divine Proportion powers! (I.e., a short green plus a medium green are the same length as a long green, and the ratio of a short to a medium is the same as a medium to a long.)

$$a:b = b:a+b$$
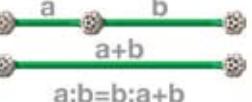
Green history

Artist Clark Richert[4] added green lines to Zometool geometry. Around 1976, he was invited (through Steve Baer) by the Art Research Center to create a Zometoy exhibit in Kansas City. Richert used the opportunity to envision a new periodic table of the elements, by packing truncated octahedra in a body-centered cubic lattice (BCC), a common structure in crystals (see Truncated Octahedron, inside.) Baer supplied struts cut to the proper lengths but they pirated holes from the red lines (a tradition we still honor!). Richert named the show "The 61-Zone Truss", since the green lines add 30 new directions to Zometool's 31 blue, yellow and red directions.
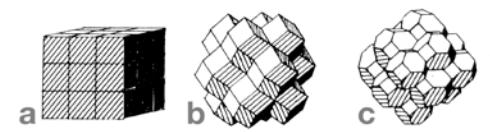
Richert's packings of cubes (a), rhombic dodecahedra (b) and truncated octahedra (c). Build them all (inside)!

Jean Baudoin, a French artist who independently discovered elements of Zometool geometry in the 1960s, used green directions in many of his sculptures. He became a strong advocate of adding green lines to Zometool (along with other implied directions[6]) and joined forces with designer Fabien Vienne to draft the current green lines. Zome nuts celebrated the first parts with a Green Party at Baudoin's Moulin de l'Image, near Chartres, in May 1999.

Models Chris Kling (informed by Steve Rogers), Brian Hall, and Scott Vorthmann give a taste of green lines' versatility.

Forever Green

Green lines may be used to build virtually an infinite number of models. ZomeSpace[7] will offer a rich environment to explore and share green line (and other Zometool) models with enthusiasts, teachers and professionals around the world.

See inside for model-building instructions, shadow activities, and more!

Endnotes

[1] For models you can't build with Zometool, try TubeSpace, designed by Fabien Vienne and Jim Hausman (see http://www.emergentworld.com)

[2] Order blue greens at 888-966-3386. But don't say we didn't warn you!

[3] "A square plot of ground 10' long by 10' wide contains a 100 square feet; ...to double this... we must find the length of a side of [a] square, so that its area... is two hundred feet. By numbers this cannot be done; for if the sides are 14 feet, these give 196 square feet; if 15 feet, they give a product of 225. Marcus Vitruvius Pollio, de Architectura, Book 9.

[4] Richert and associates conceived of "the first hippie commune," Drop City, in Spring of 1964. "We envisioned a whole city as a live-in work of Drop Art." Built on 7 acres of pasture near Trinidad, Colorado, Drop City was awarded R. Buckminster Fuller's Dymaxion Award in 1969.

[5] The physical embodiment of the 31-zone system, Zometoy was developed by Steve Baer and associates of Zomeworks Corporation in the early 1970s. Zometoy kits consisted of soft polyethylene "Whiffle" balls and wooden "Tinkertoy" struts in a wooden case, with Baer's Zome Primer as a manual.

[6] Baudoin and Vienne called these other lines the "bleu, jaune, et rouge symmetrique" (blue, yellow and red symmetricals). They are represented in Scott Vorthmann's vZome program as black, purple and orange lines, and in conjunction with the 61-zone system comprise the 181-zone system. Still other lines have been identified by Vorthmann and associates.

[7] ZomeSpace model database is in development as of this writing (3/2009). Used with ZomePad software, it allows you to share models and ideas with the global circle of Zometool users. See www.zometool.com for more info.

Octahedron

Shadows

Tetrahedron
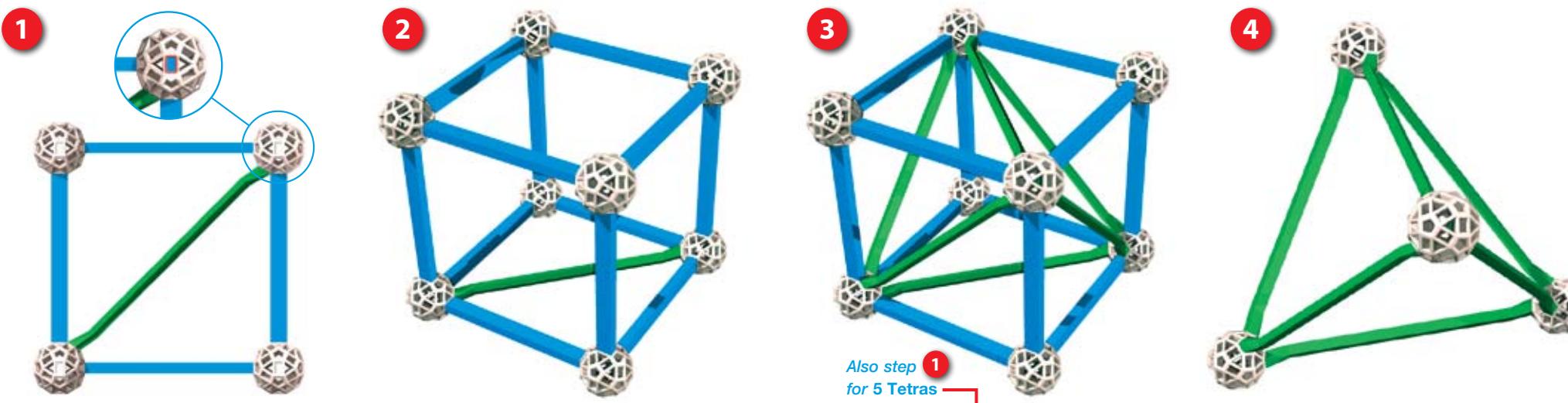
Also step ① for 5 Tetras

---

1. Place a blue or yellow strut* in any hole.
2. Point the strut at the sun.
3. Cast shadow on a board at 90° to sun's rays.

*Use a red strut to get a 5-fold shadow (see 5 Tetras).
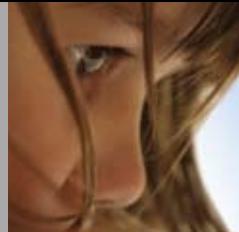
Our mission:
- make learning fun
- create value
- build a better world
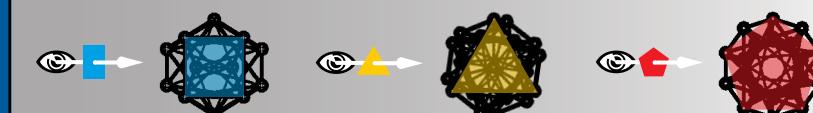
5 Tetras   *11.3*
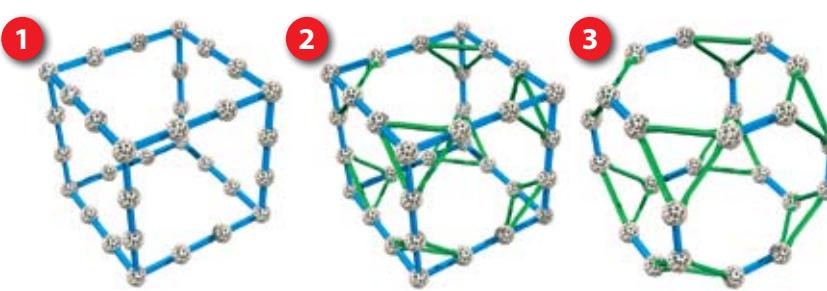
Truncated Cube*   *3.4**
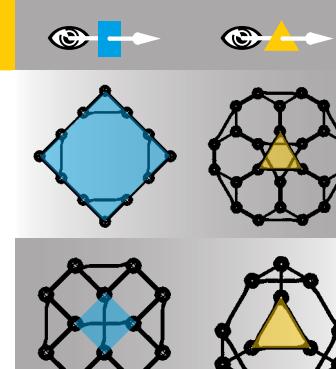
Truncated Tetrahedron   *3.4*
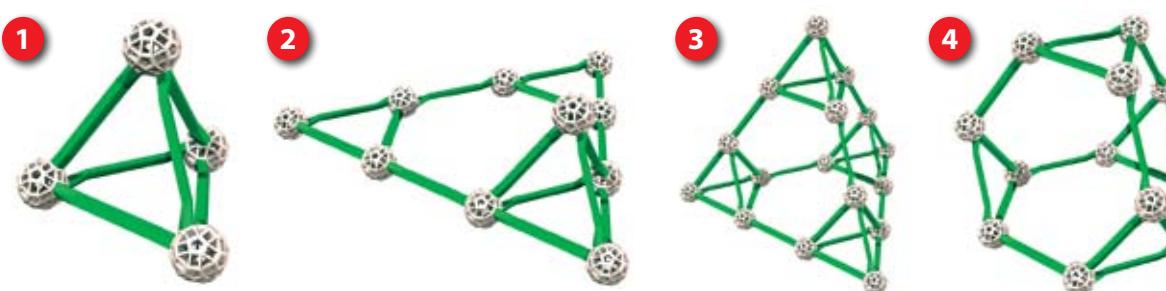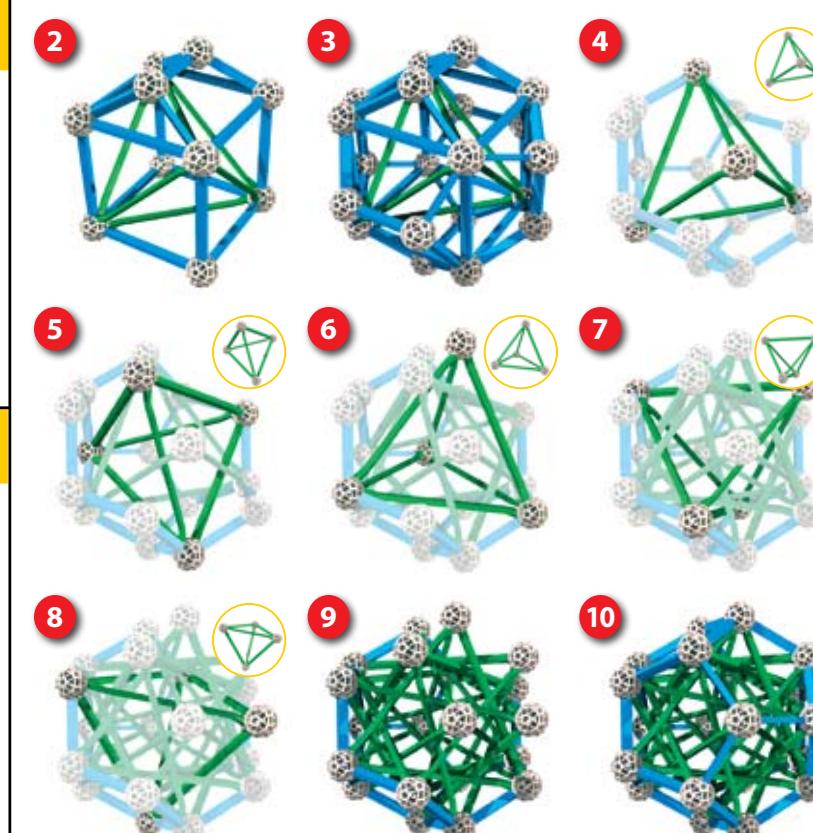
Hexagonal Slice Through Cube   *3.1.5*
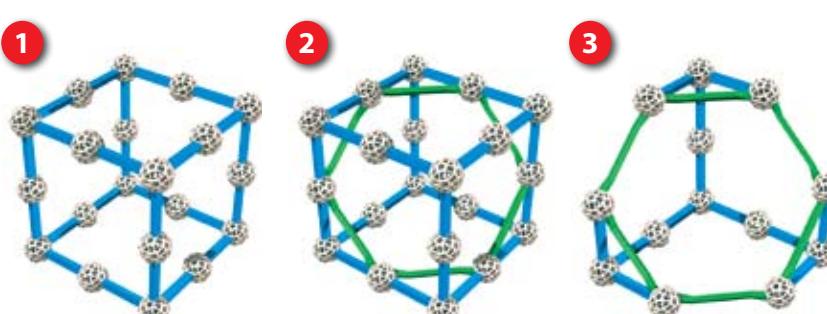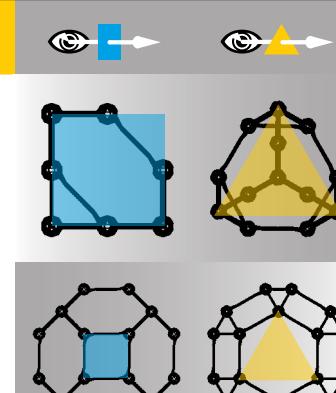

Truncated Octahedron   *3.4*
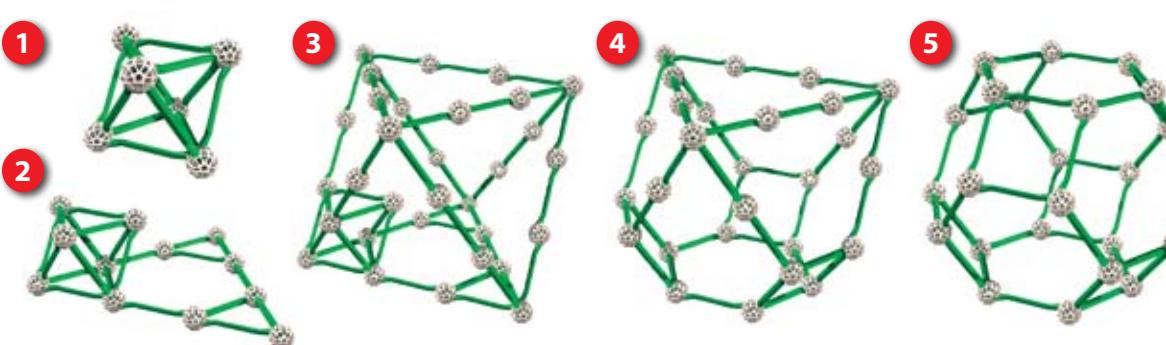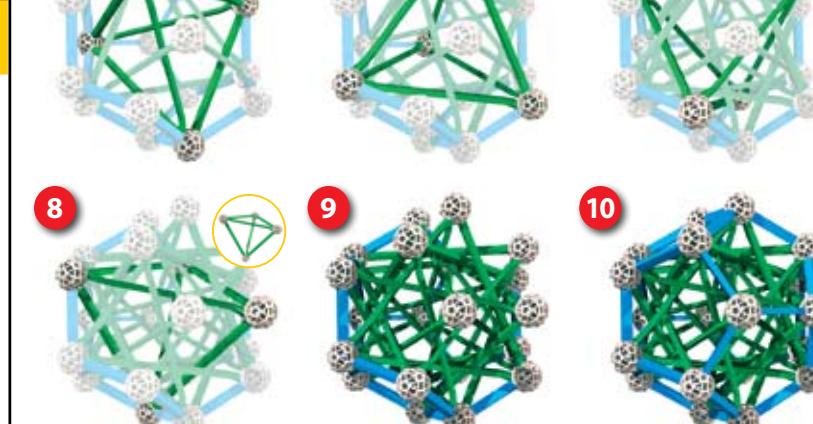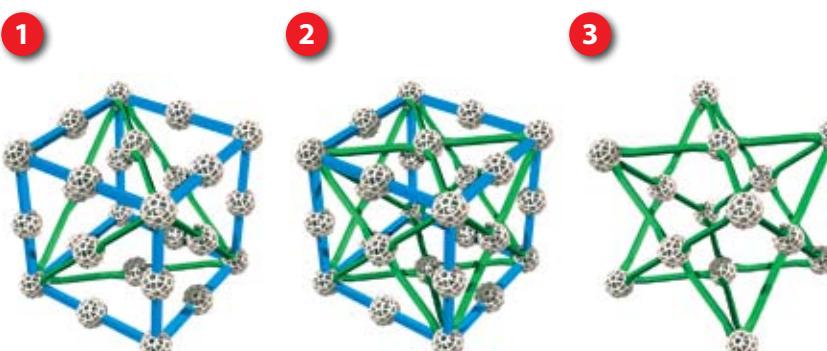
Stella Octangula   *3.2.3*
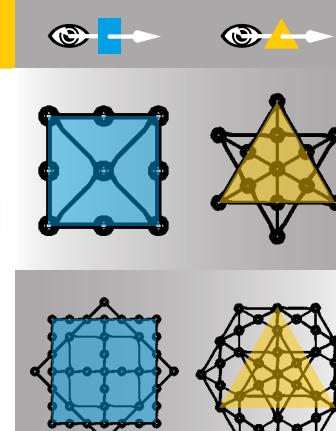
Cuboctahedron & Rhombic Dodecahedron   *12B*
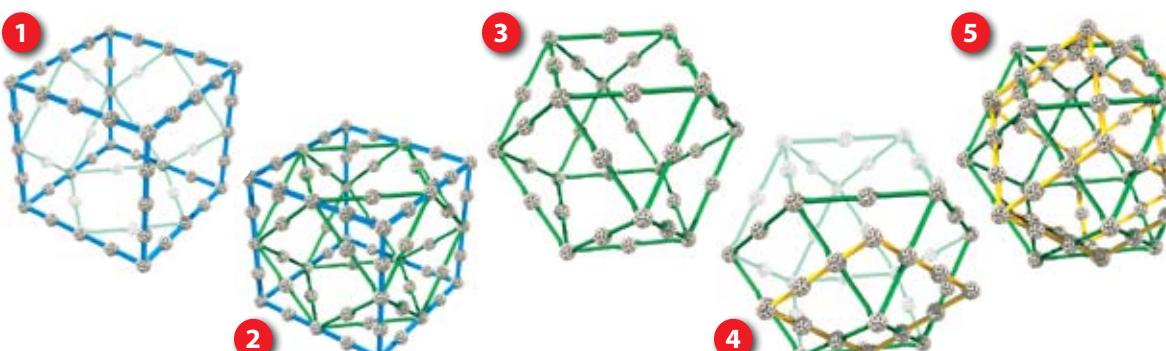
---
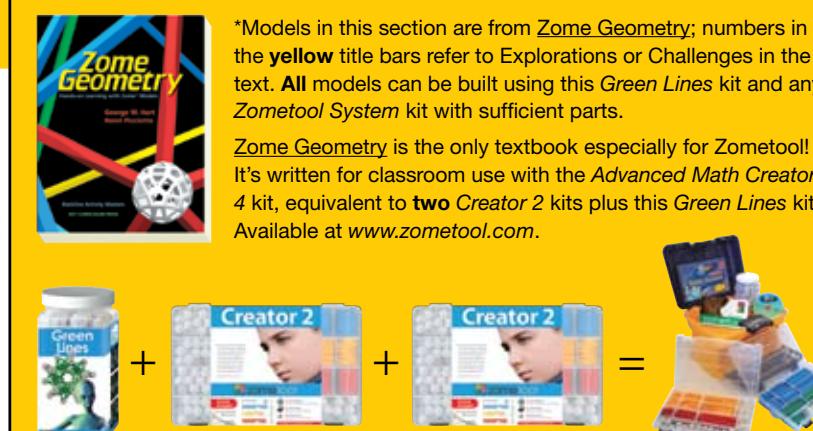
*Models in this section are from Zome Geometry; numbers in the **yellow** title bars refer to Explorations or Challenges in the text. **All** models can be built using this *Green Lines* kit and any *Zometool System* kit with sufficient parts.

Zome Geometry is the only textbook especially for Zometool! It's written for classroom use with the *Advanced Math Creator 4* kit, equivalent to **two** *Creator 2* kits plus this *Green Lines* kit. Available at *www.zometool.com*.