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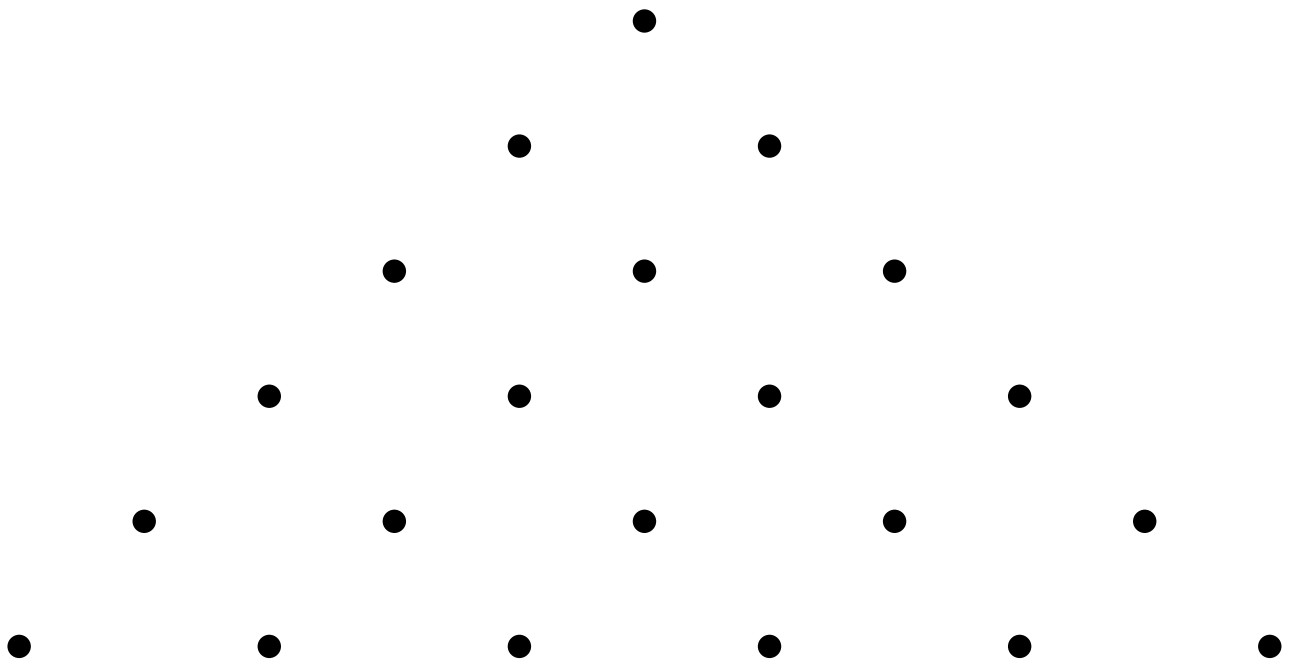
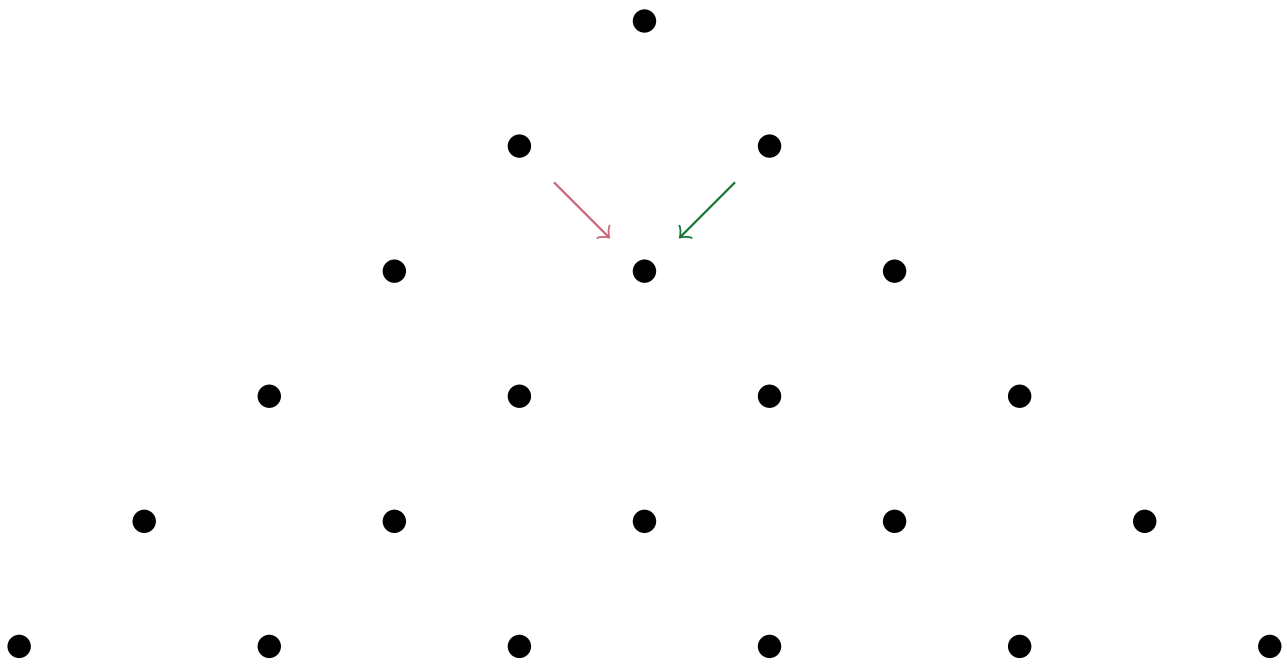
We want to expand $(x+h)^n$.

Pascal's Triangle



Pascal's Triangle



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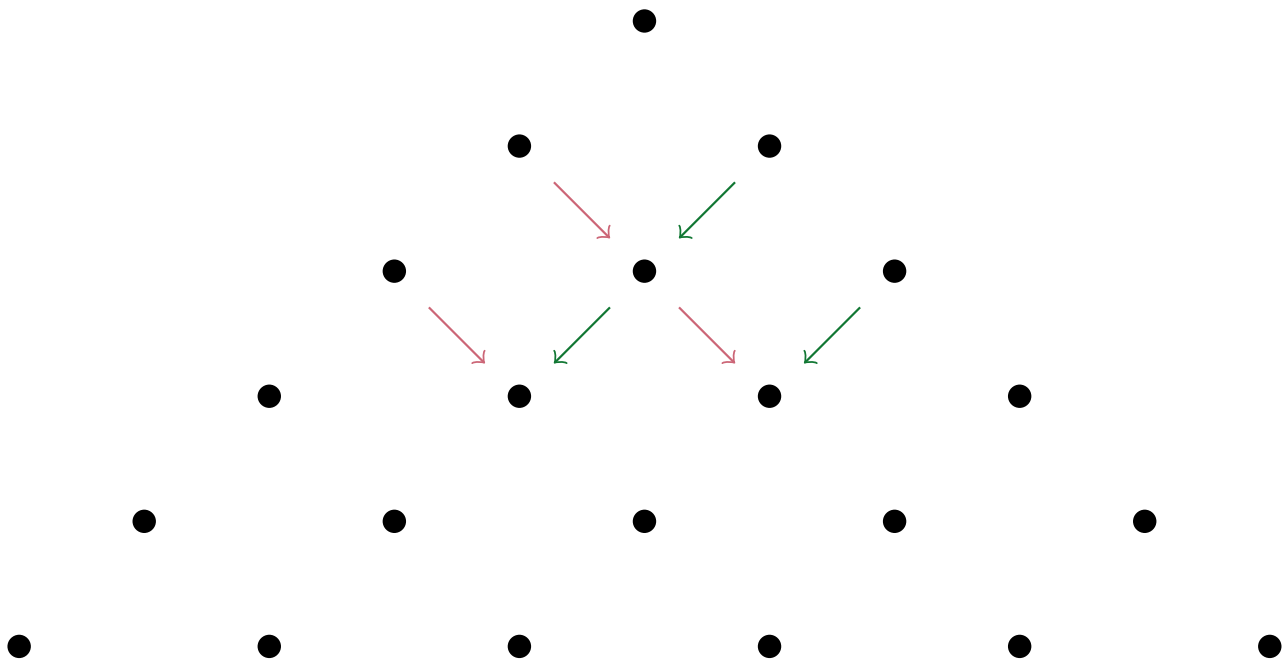

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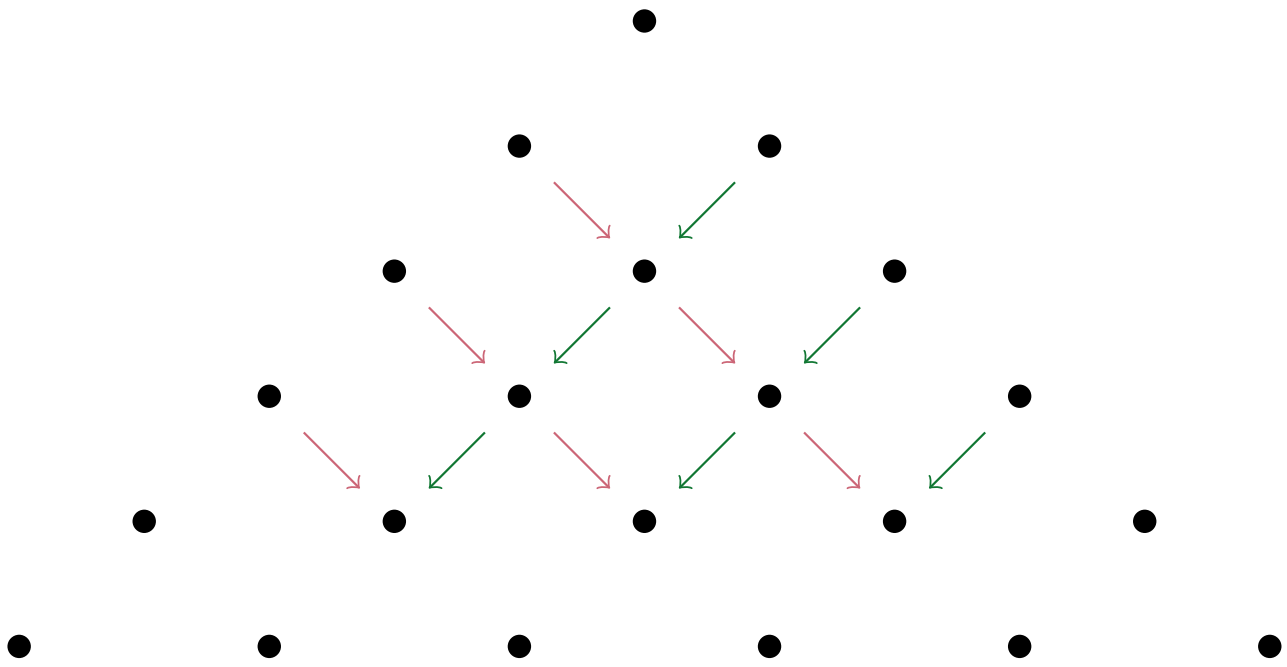

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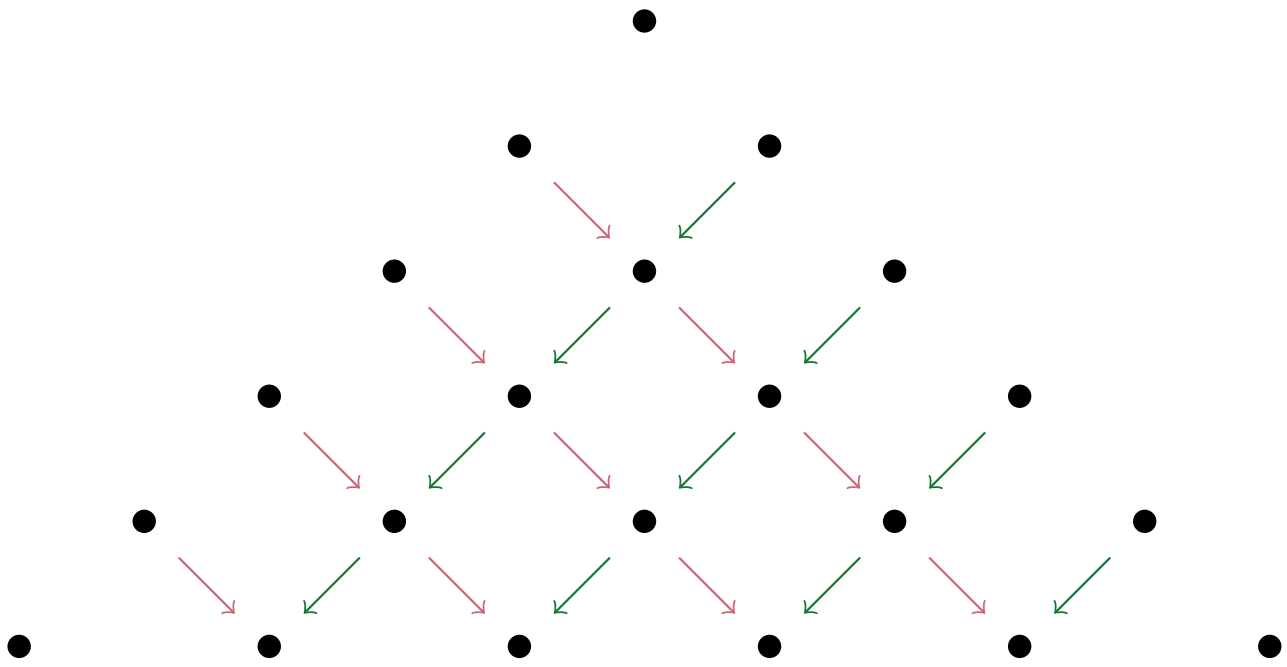

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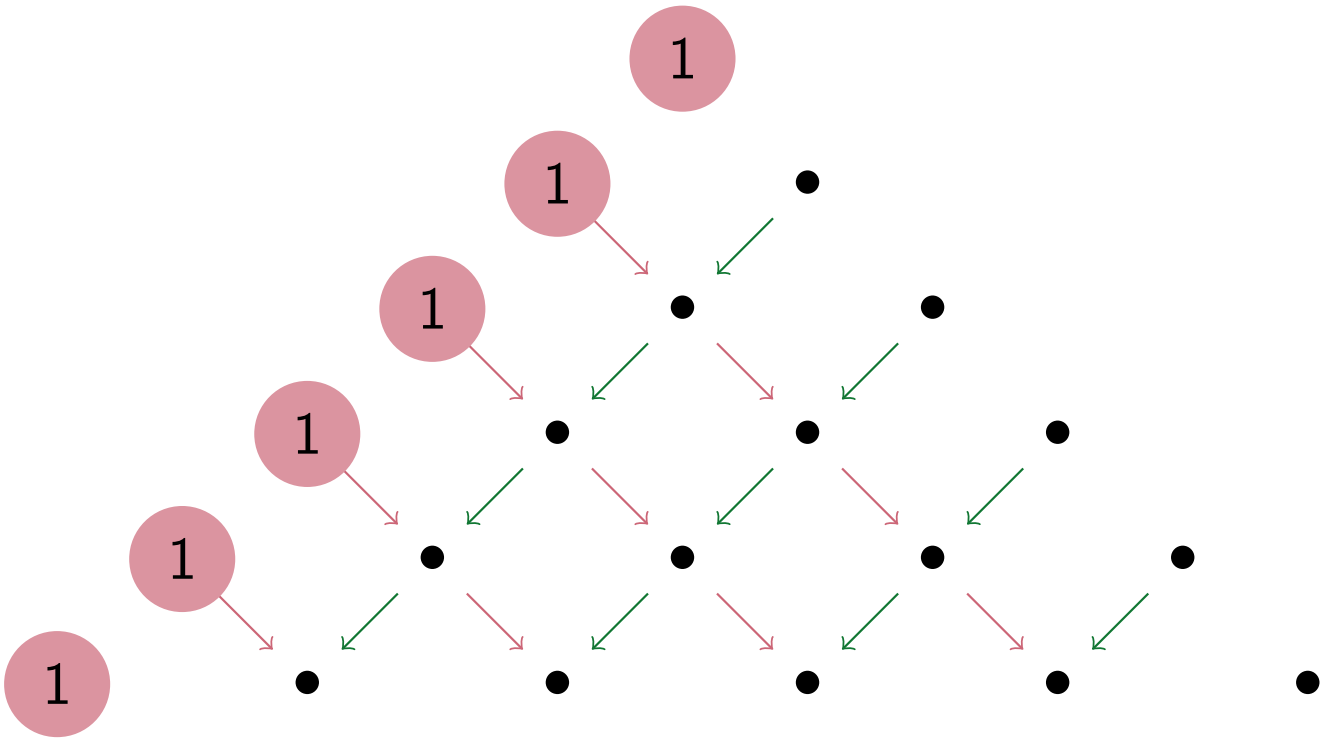

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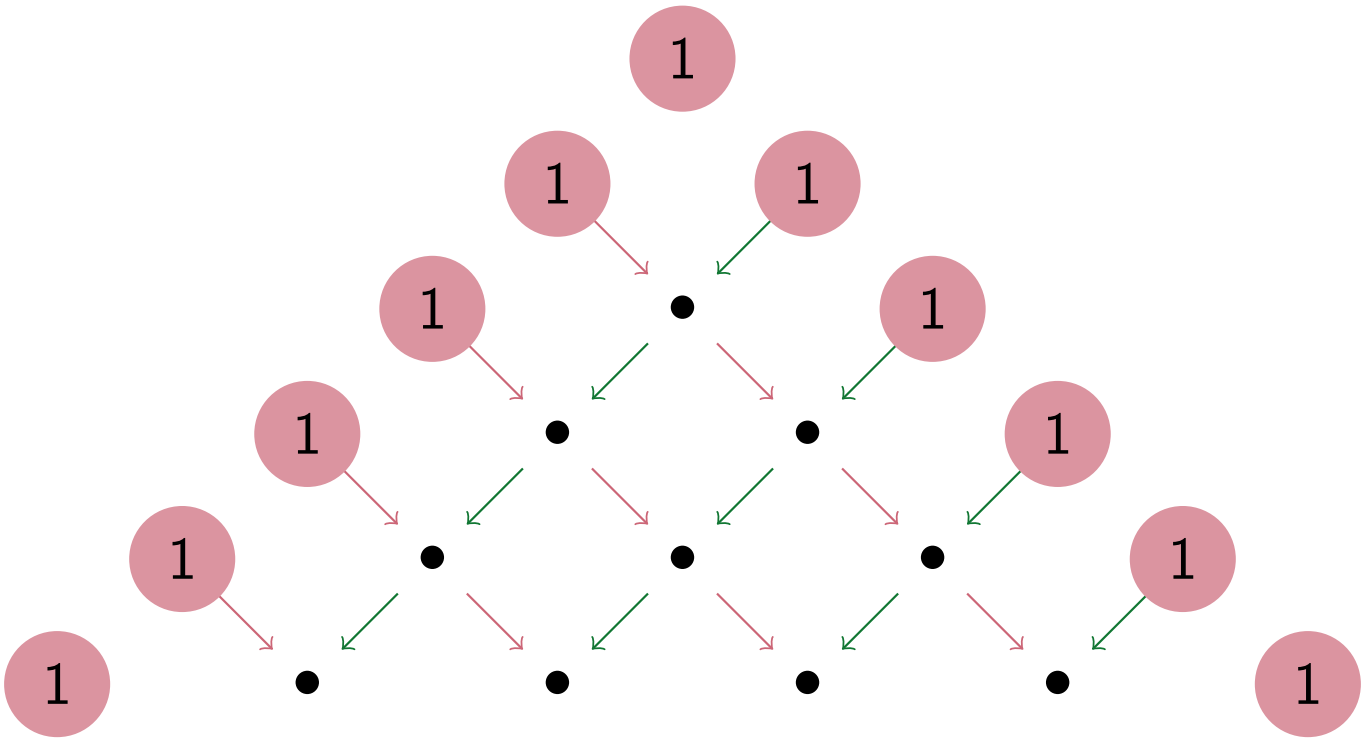

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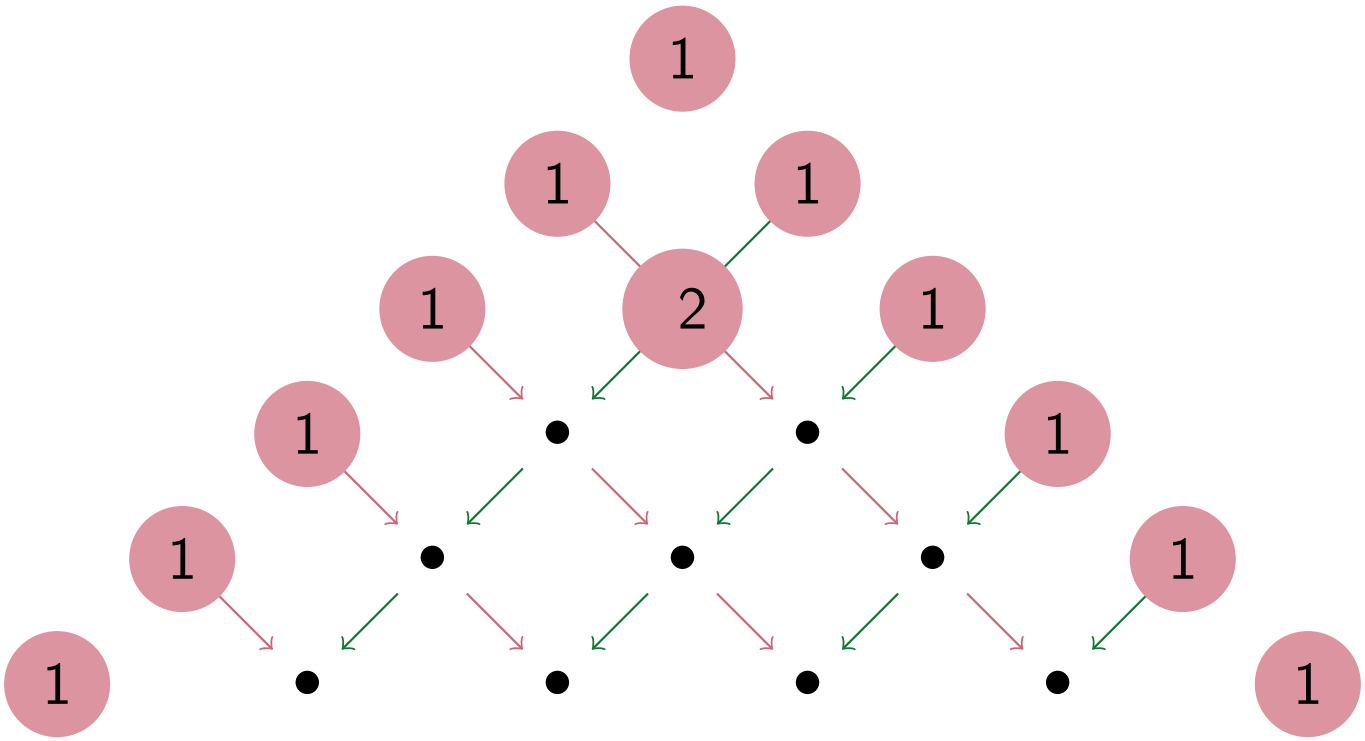

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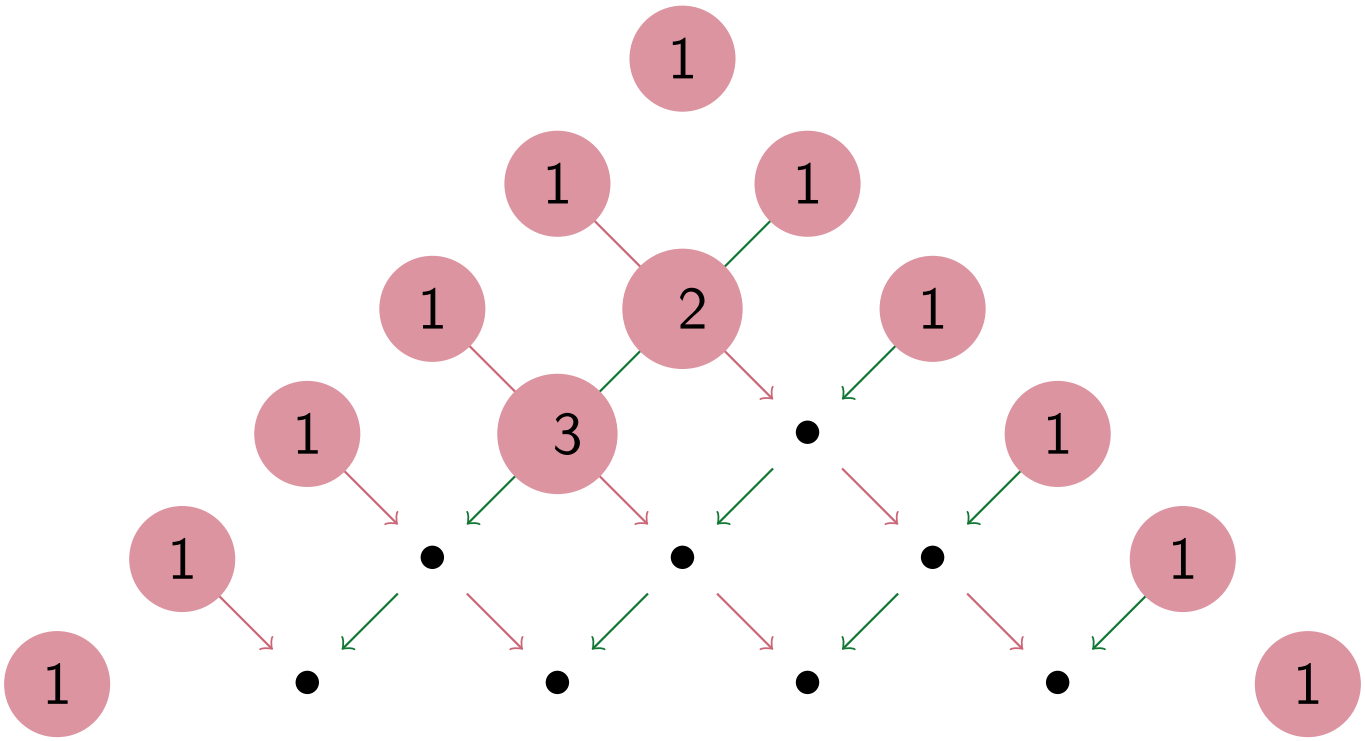

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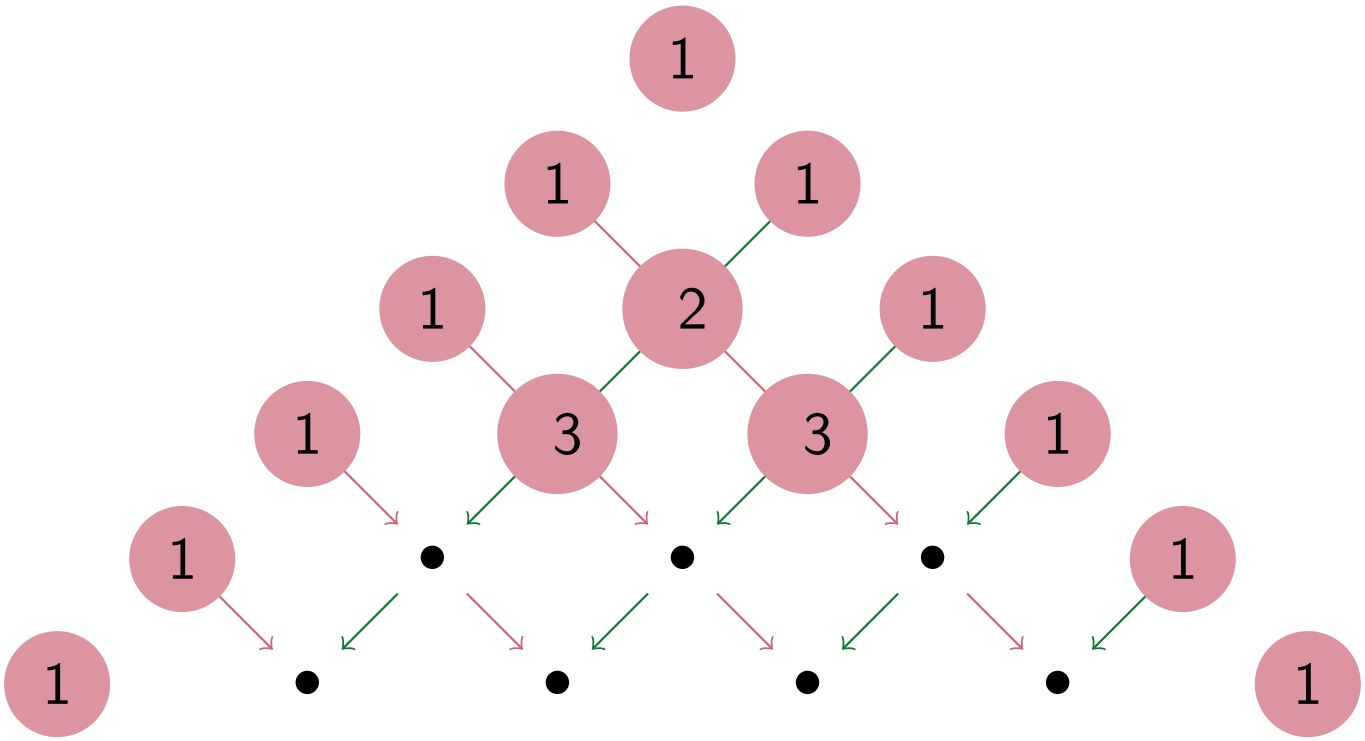

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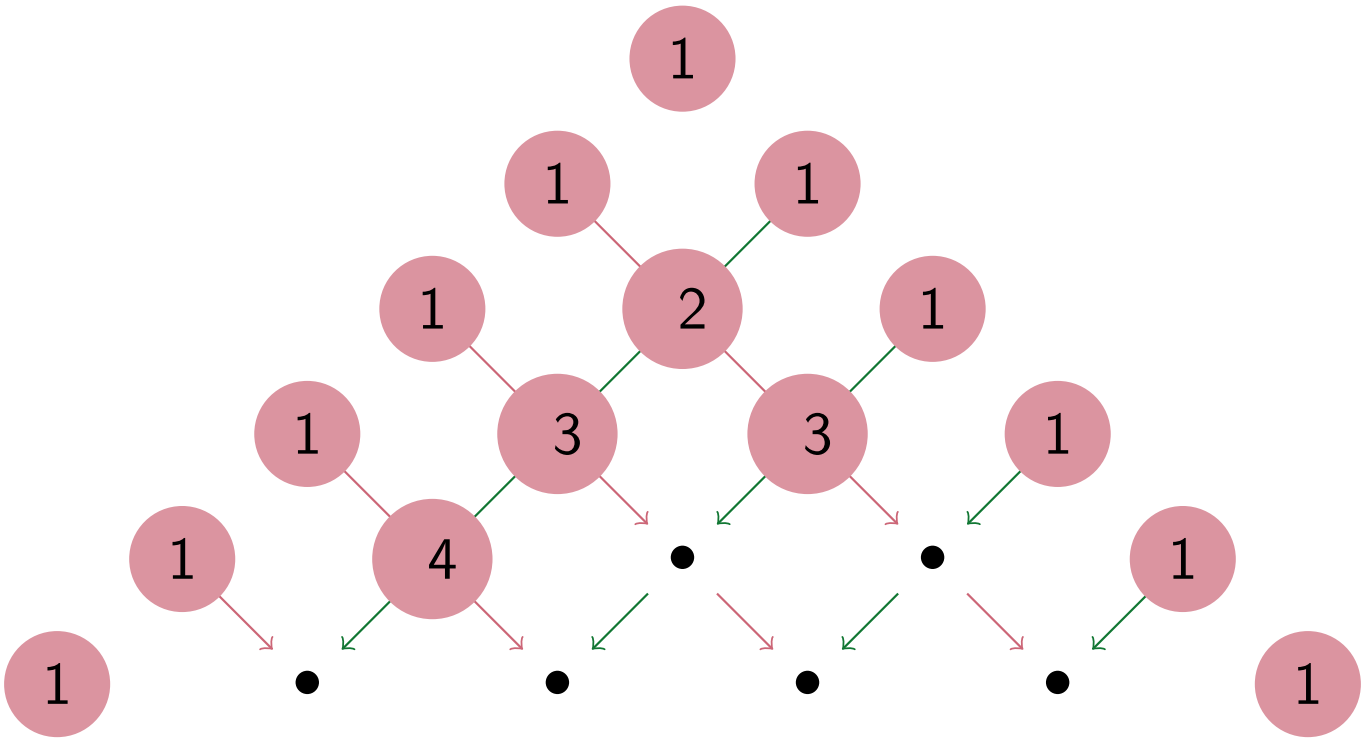

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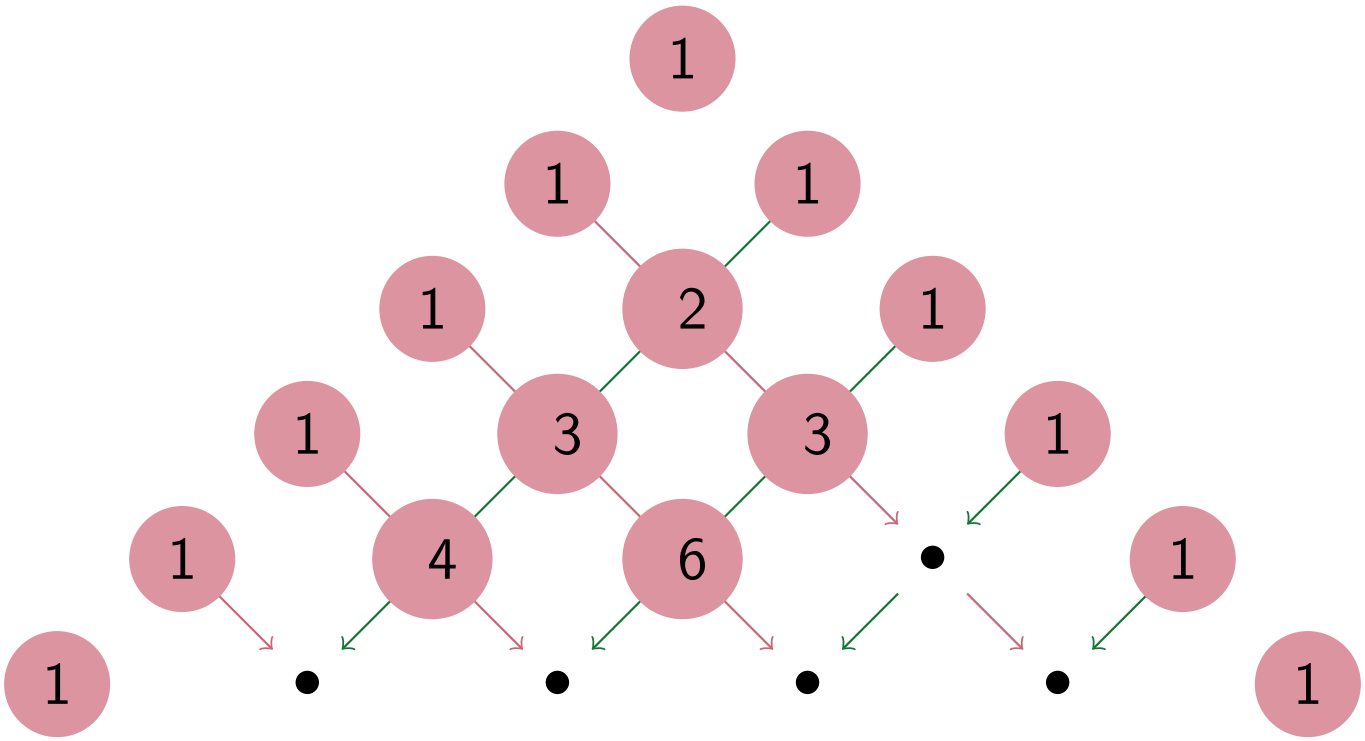

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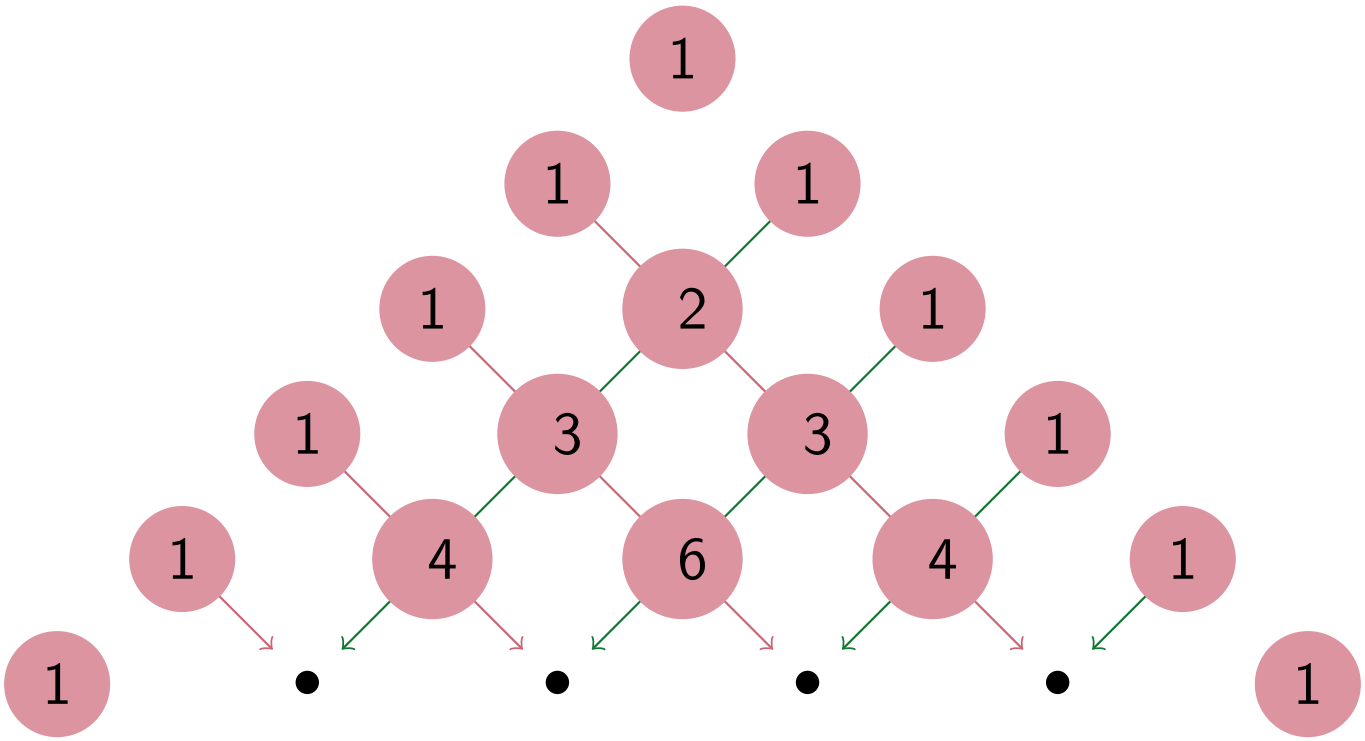

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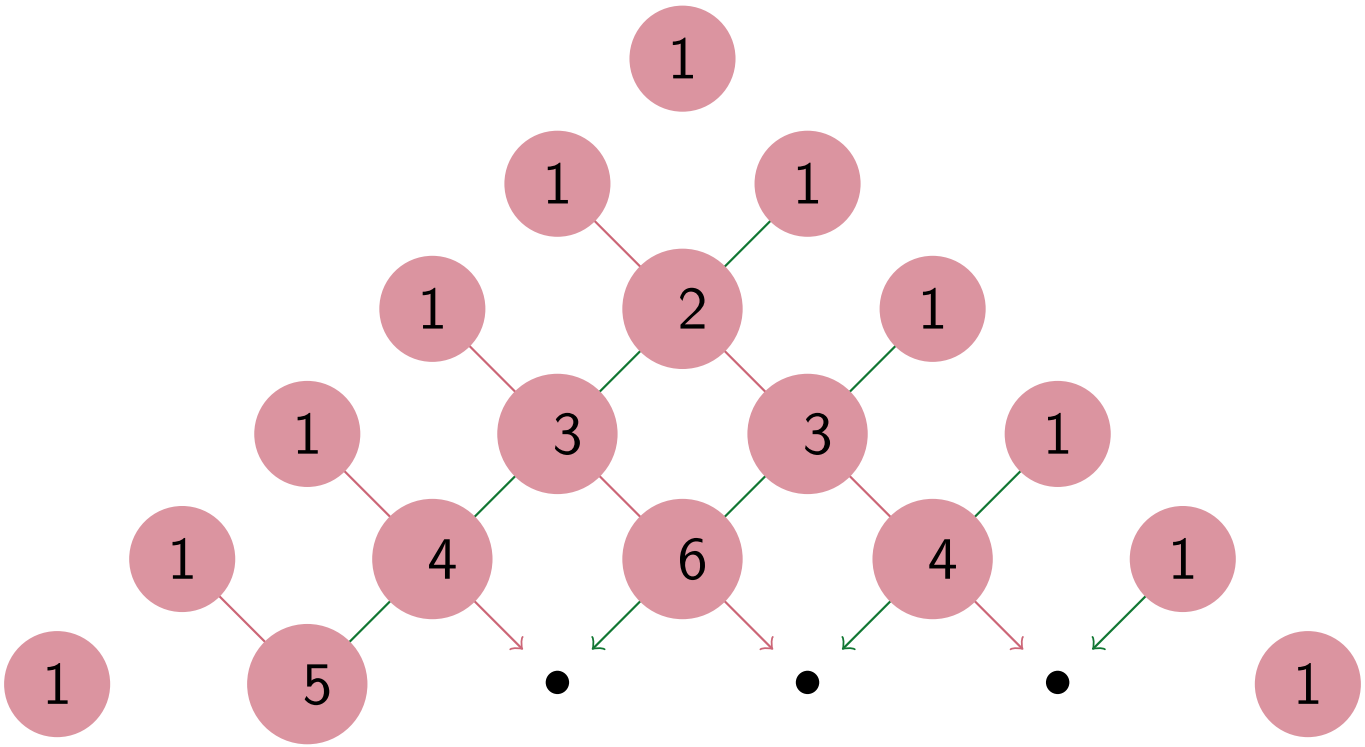

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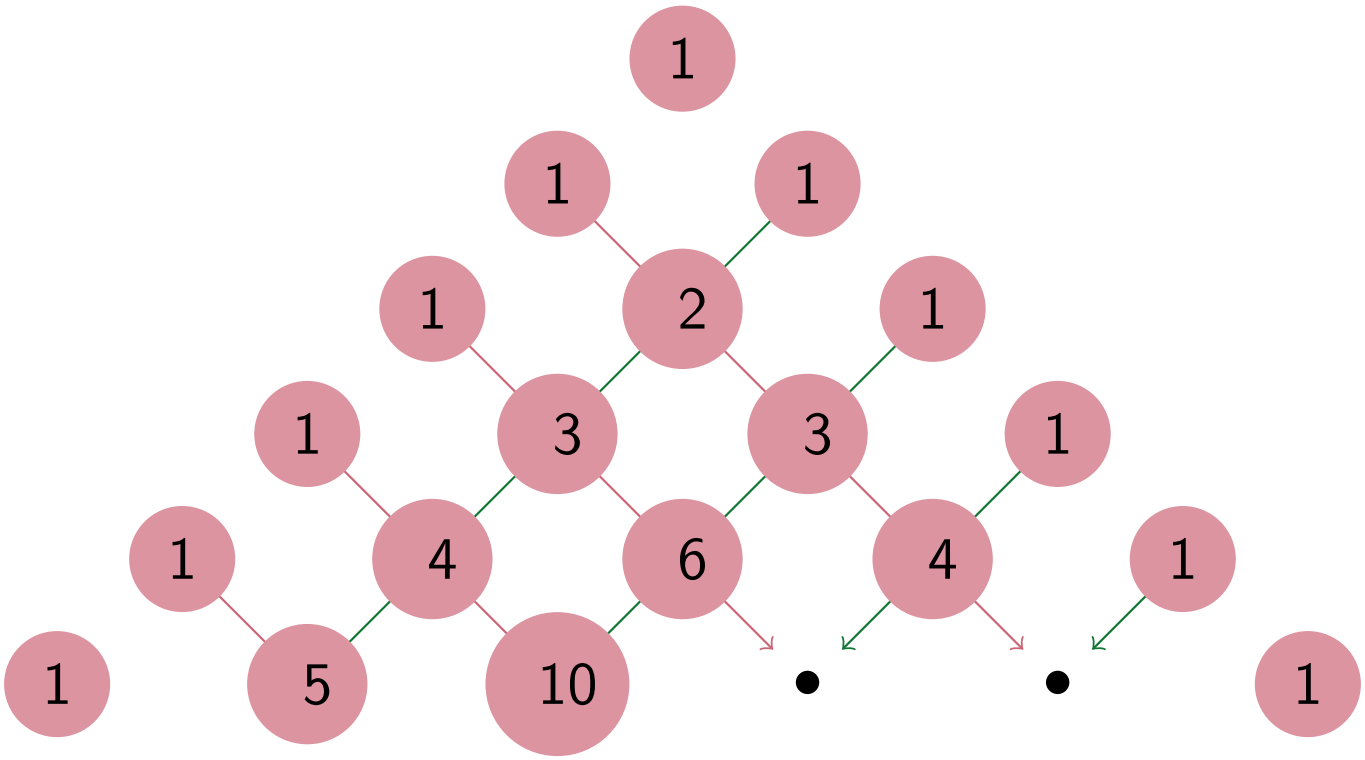

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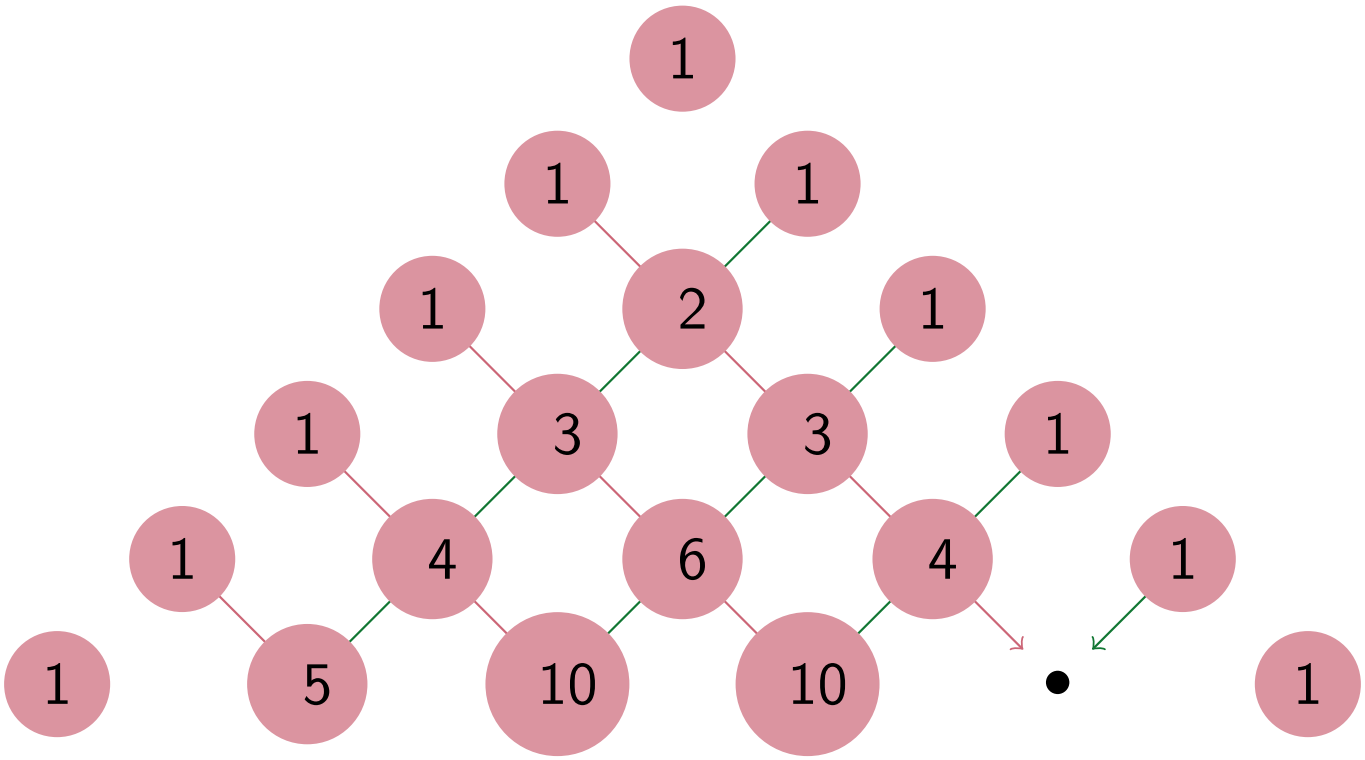

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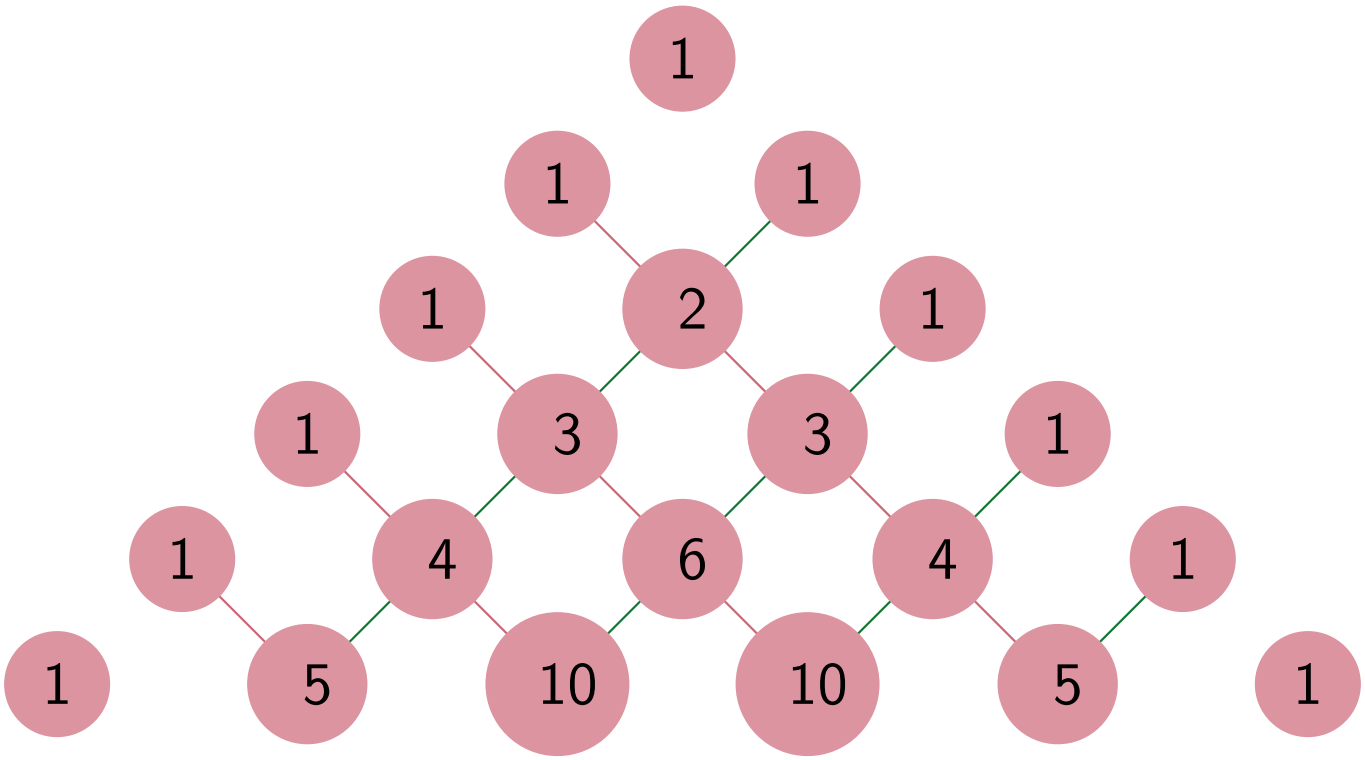

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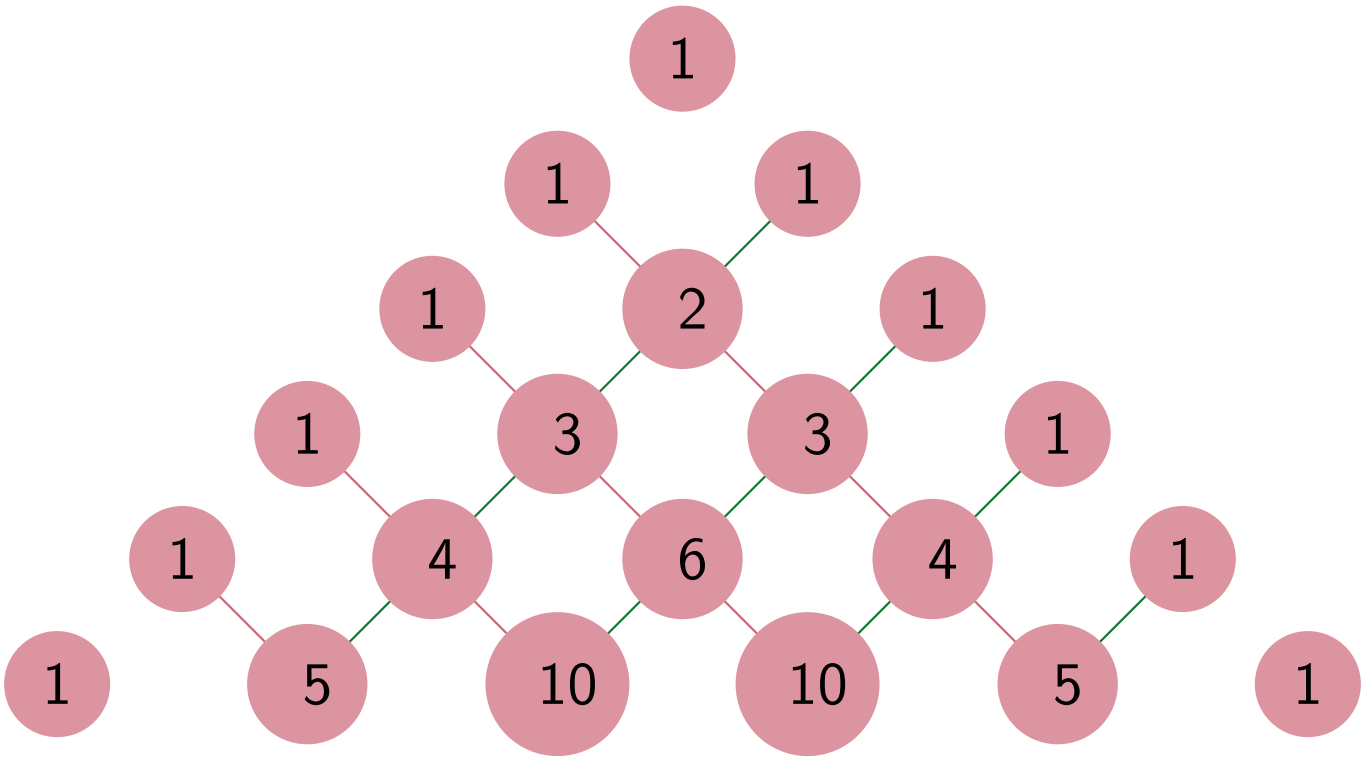

$$(x+h)^2 = x^2 + 2xh + h^2$$

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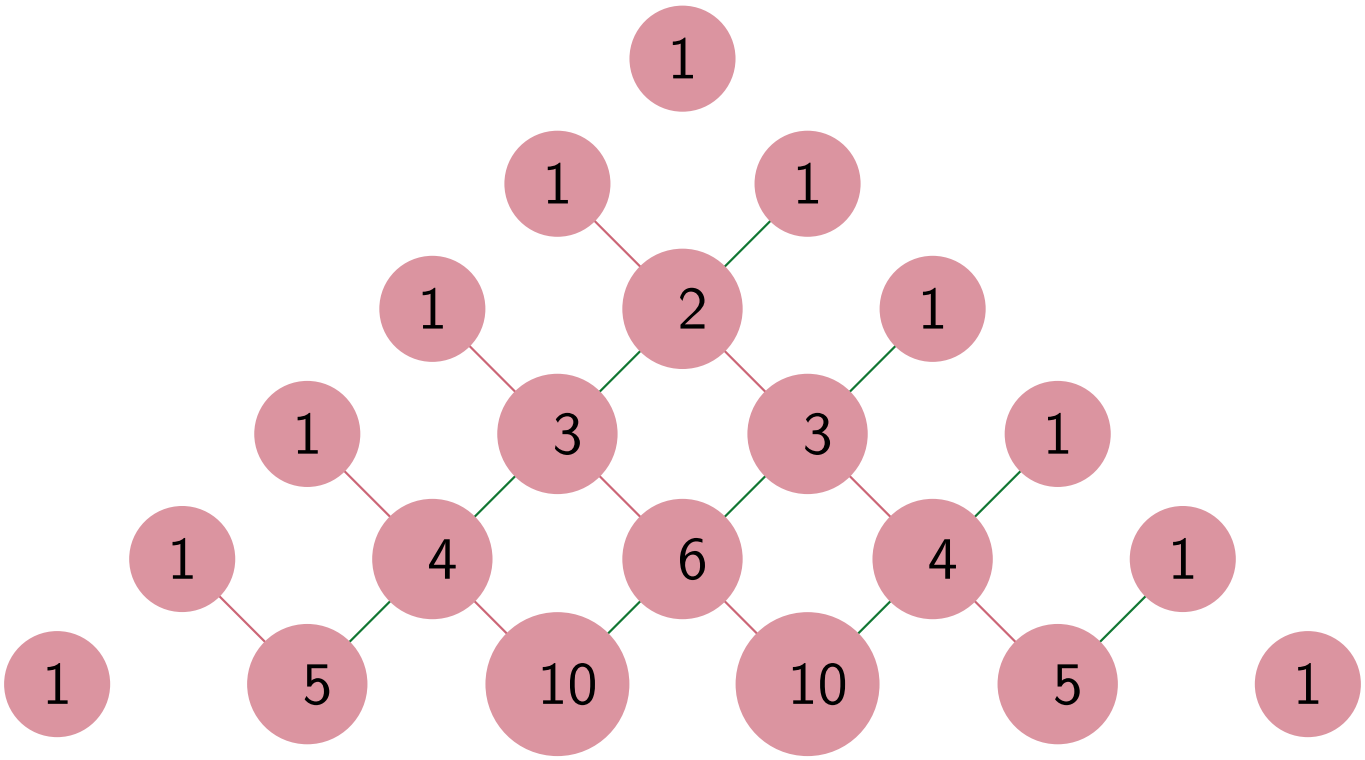

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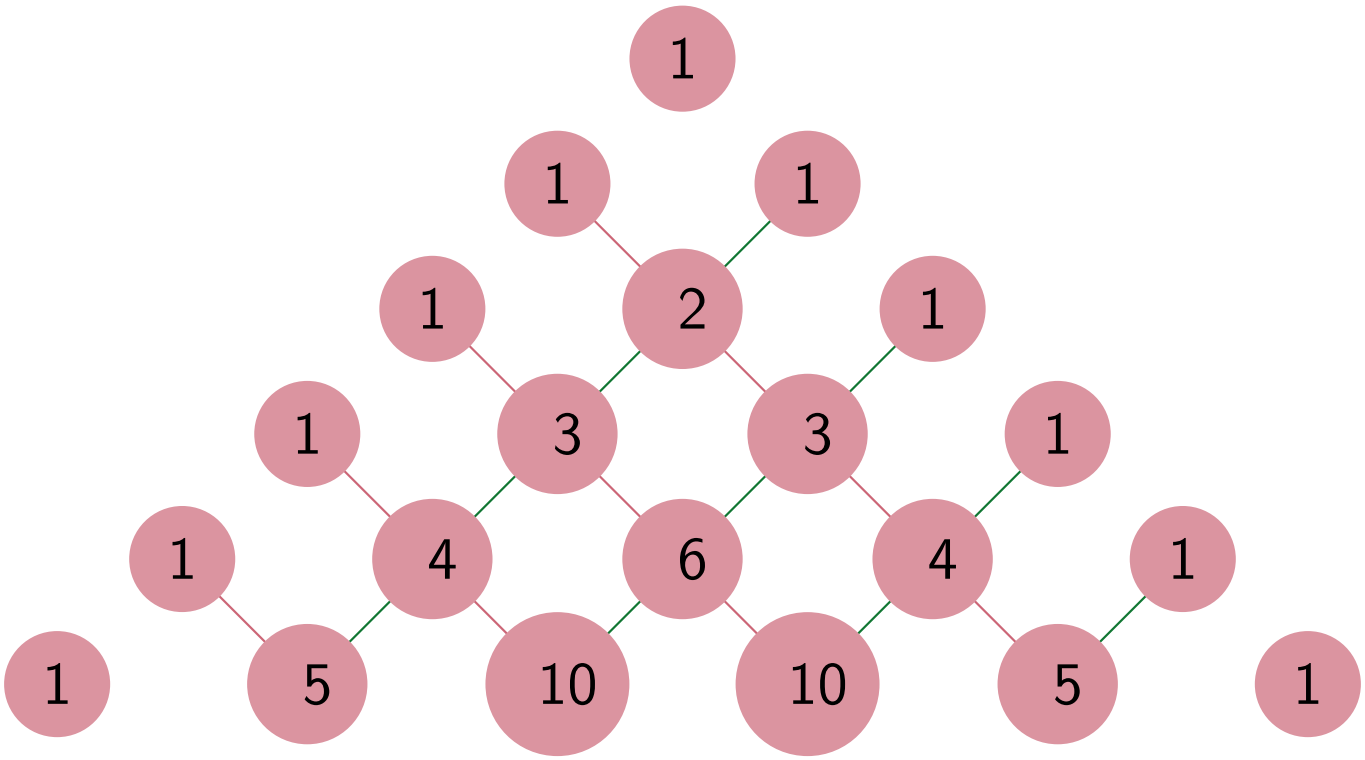

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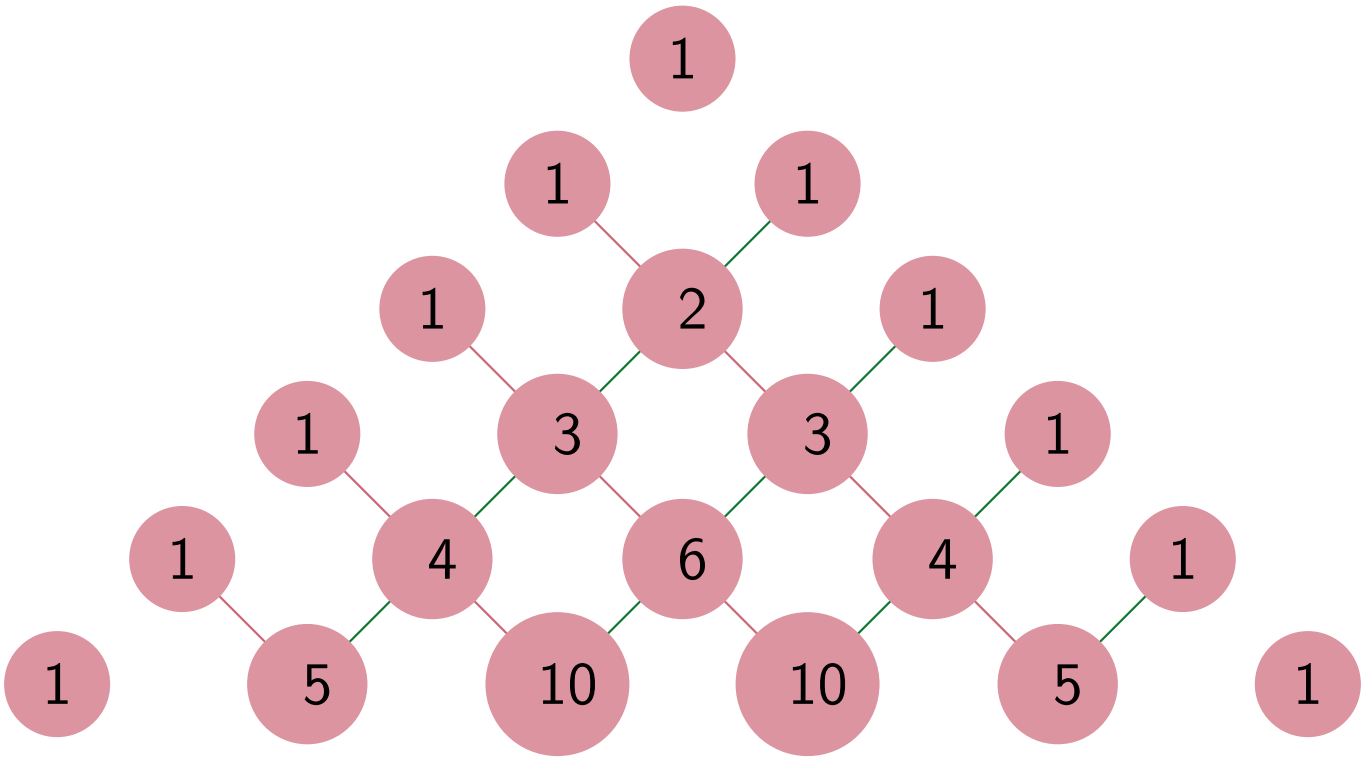

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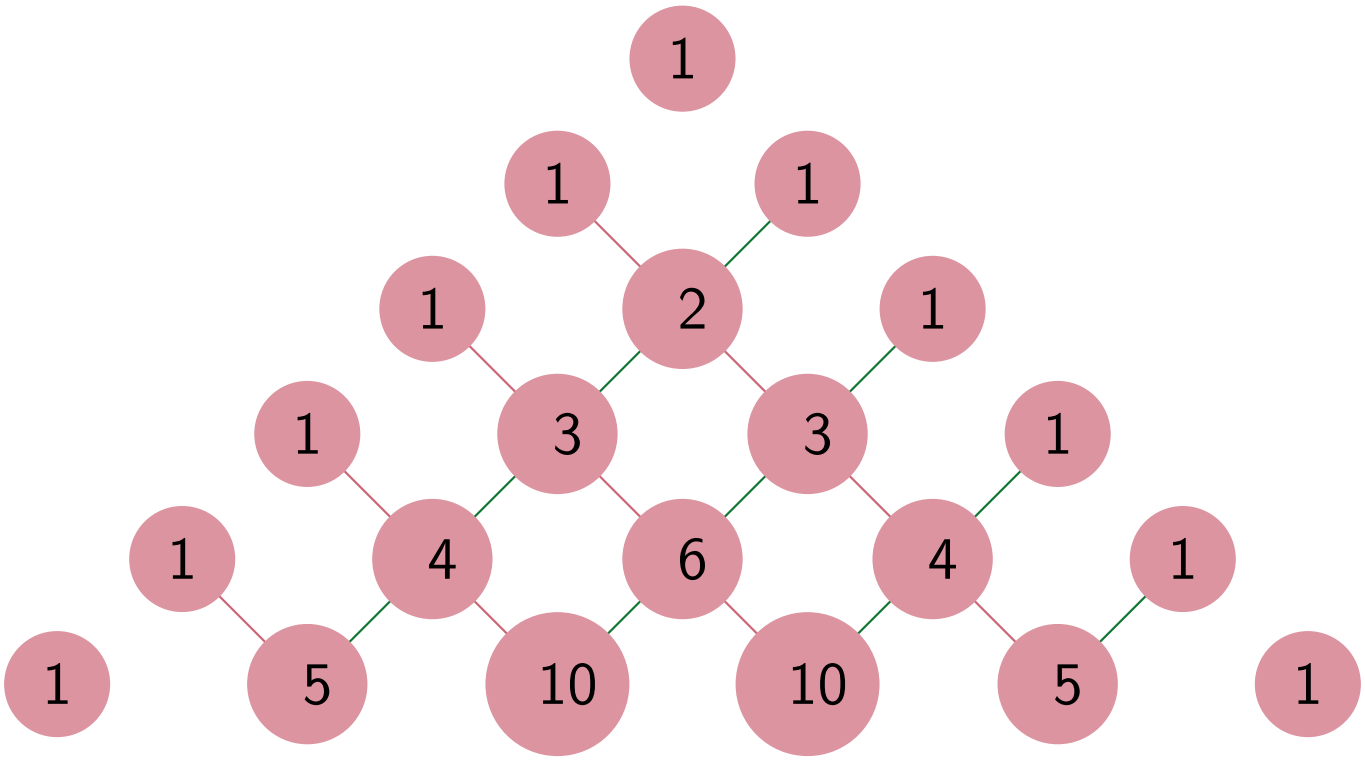

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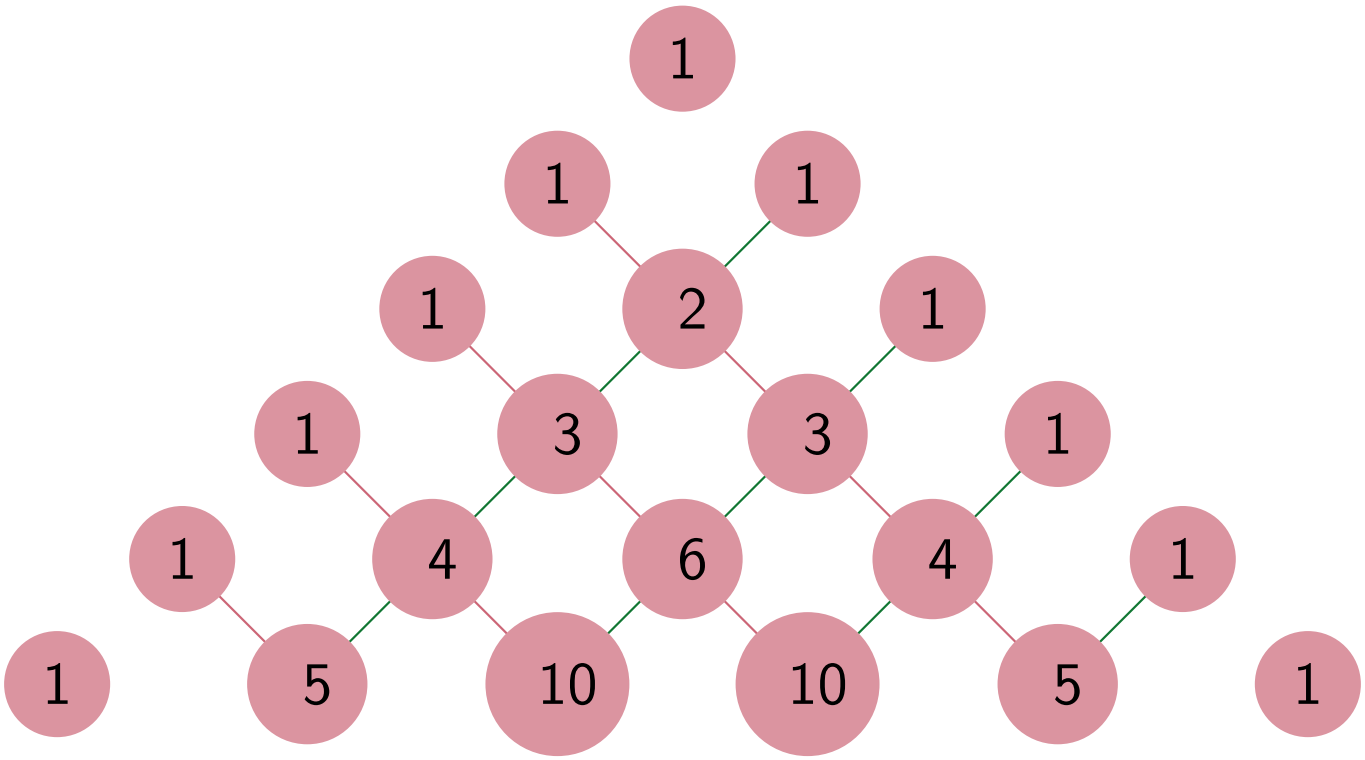

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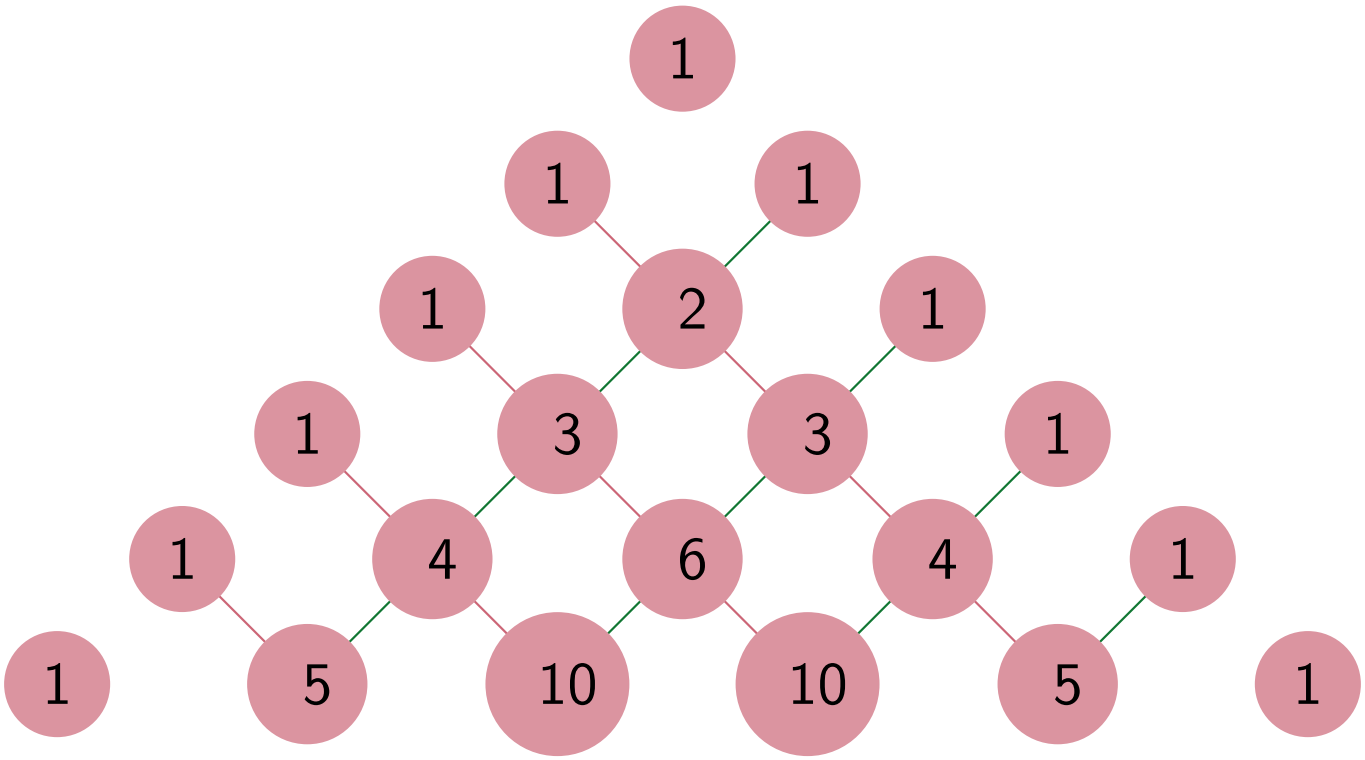

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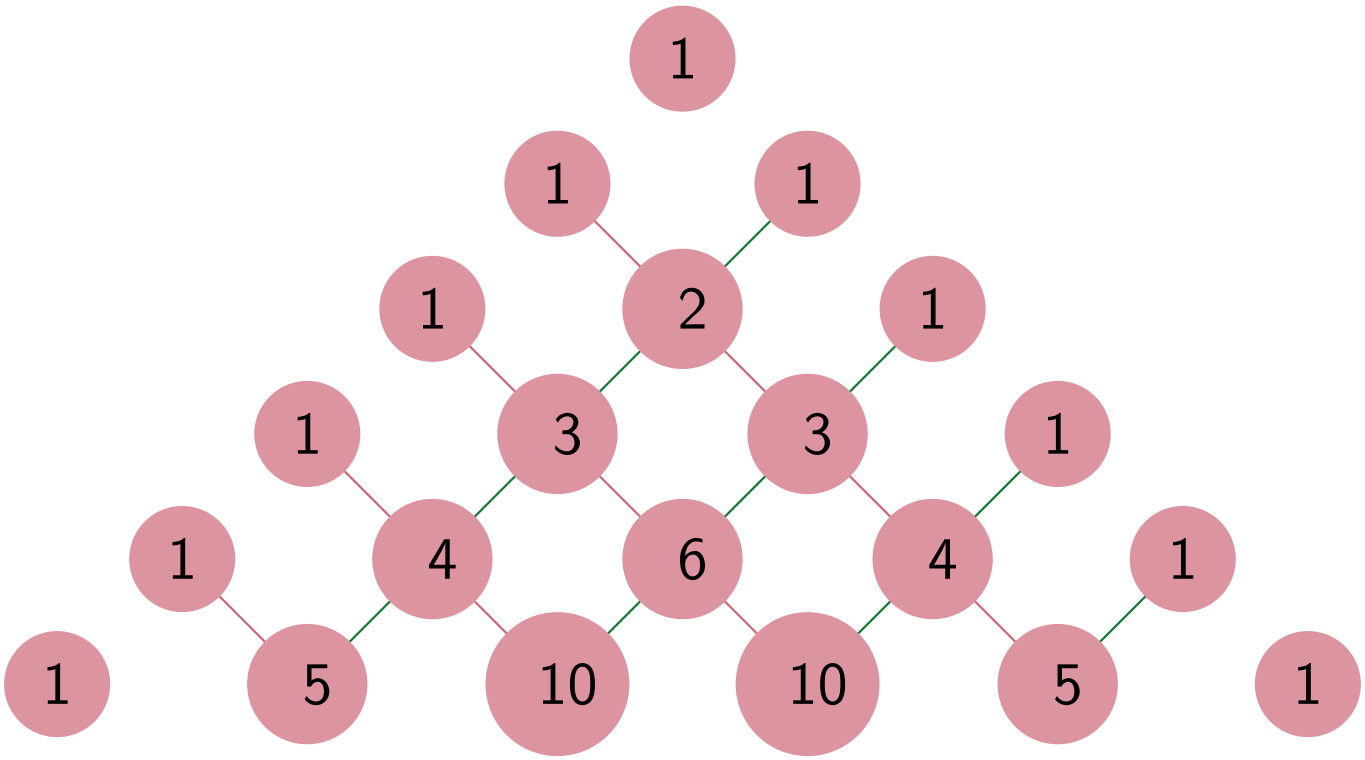

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$$
\begin{aligned}
\frac{\mathrm{d}}{\mathrm{d}x}\{x^n\} &= \lim_{h\to 0}\frac{(x+h)^n - x^n}{h} \\
&= \lim_{h\to 0}\frac{\left(x^n + nx^{n-1}h + \square x^{n-2}h^2 + \square x^{n-3}h^3 + \cdots\right) - x^n}{h} \\
&= \lim_{h\to 0}\frac{\left(nx^{n-1}h + \square x^{n-2}h^2 + \square x^{n-3}h^3 + \cdots\right)}{h}
\end{aligned}
$$

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&= \lim_{h\to 0} \frac{\left(x^n + nx^{n-1}h + \square x^{n-2}h^2 + \square x^{n-3}h^3 + \cdots\right) - x^n}{h} \\
&= \lim_{h\to 0} \frac{\left(nx^{n-1}h + \square x^{n-2}h^2 + \square x^{n-3}h^3 + \cdots\right)}{h} \\
&= \lim_{h\to 0} nx^{n-1} + \square x^{n-2}h + \square x^{n-3}h^2 + \cdots
\end{aligned}
$$

Power Rule

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\begin{aligned}
\frac{\mathrm{d}}{\mathrm{d}x}\{x^n\} &= \lim_{h\to 0} \frac{(x+h)^n - x^n}{h} \\
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&= \lim_{h\to 0} \frac{\left(nx^{n-1}h + \square x^{n-2}h^2 + \square x^{n-3}h^3 + \cdots\right)}{h} \\
&= \lim_{h\to 0} nx^{n-1} + \square x^{n-2}h + \square x^{n-3}h^2 + \cdots \\
&= nx^{n-1} + \square x^{n-2}(0) + \square x^{n-3}(0)^2 + \cdots
\end{aligned}
$$

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\begin{aligned}
\frac{\mathrm{d}}{\mathrm{d}x}\{x^n\} &= \lim_{h\to 0} \frac{(x+h)^n - x^n}{h} \\
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&= \lim_{h\to 0} \frac{\left(nx^{n-1}h + \square x^{n-2}h^2 + \square x^{n-3}h^3 + \cdots\right)}{h} \\
&= \lim_{h\to 0} nx^{n-1} + \square x^{n-2}h + \square x^{n-3}h^2 + \cdots \\
&= nx^{n-1} + \square x^{n-2}(0) + \square x^{n-3}(0)^2 + \cdots \\
&= nx^{n-1}
\end{aligned}
$$

That is, $\frac{\mathrm{d}}{\mathrm{d}x}\{x^n\} = nx^{n-1}$.